

Scandinavian Journal of Plastic and Reconstructive Surgery

SUPPLEMENTUM 12

ON LE FORT I OSTEOTOMY

A follow-up study of 106 operated patients
with maxillo-facial deformity

BY
KARIN WILLMAR

Distributed by Almqvist & Wiksell/Stockholm/Sweden

June 1974

ON LE FORT I OSTEOTOMY

A follow-up study of 106 operated patients
with maxillo-facial deformity

AKADEMISK AVHANDLING

som med vederbörligt tillstånd av Odontologiska
fakulteten vid universitetet i Lund för vinnande
av odontologie doktorsgrad kommer att offentligen
försvaras å Tandläkarhögskolans aula, Malmö torsdagen
den 16 maj 1974 kl 9.00.

av

KARIN WILLMAR
leg. tandläkare

SCANDINAVIAN JOURNAL OF
PLASTIC AND RECONSTRUCTIVE SURGERY
SUPPLEMENTUM 12

*From the Department of Plastic Surgery and the
Maxillo-Facial Center, Malmö General Hospital and
the Departments of Orthodontics, School of Dentistry
and of Otolaryngology, Malmö General Hospital,
(University of Lund), Malmö, Sweden.*

ON LE FORT I OSTEOTOMY

A follow-up study of 106 operated patients
with maxillo-facial deformity

BY
KARIN WILLMAR

Stockholm 1974

Translated by Mr L. James Brown
Medical terminology revised by
Dr Sherman N. Leis.



Printed in Sweden by
Sydsvenska Dagbladets Aktiebolag, Malmö 1974

CONTENTS

INTRODUCTION	5
ANATOMICAL REMARKS	6
BRIEF HISTORICAL BACKGROUND.....	8
MATERIAL AND METHODS	10
RESULTS	19
GENERAL DISCUSSION.....	56
SUMMARY	59
APPENDIX: TABLES	61
REFERENCES	67

INTRODUCTION

People with congenital and acquired malformations of the face frequently suffer from a feeling of inferiority and are often the victim of undue attention and disturbing remarks. It is therefore readily understood how facial anomalies may lead to emotional and social maladjustment, problems which have now begun to receive their just attention by psychiatrists and psychologists (*Walker & Collins*, 1971, *Hviid*, 1972 and others). Facial anomalies with or without dental malocclusion have long attracted the interest of the medical and dental professions. Various surgical and dental-orthopaedic methods for correction of dento-facial abnormalities have been published (*Lane* 1905, *Aleman* 1921, *Pichler* 1929, *Trauner & Obwegeser* 1957, *Köle* 1963).

The prognathous mandible, for example, has been surgically treated for more than seventy years by osteotomy and repositioning of the lower jaw (*Wassmund* 1935, *Hogeman* 1951, *Thoma* 1963). Operations on the mandible have been used for correcting so-called pseudopognathism, a condition with a predominant reposition of the upper jaw and anterior crossbite (*Kostecka* 1937, *Immenkamp* 1938). Experience with this method of backward shifting of the mandible has indicated that the result of the operation may be a retruded face (*Wassmund* 1935, *Trauner* 1973). Here, the surgical and dental-orthopaedic methods should have been directed towards the maxilla.

To avoid the unsatisfactory effect encountered with earlier operations for pseudopognathism, it was decided to attempt anterior mobilization of the maxilla by Le Fort I osteotomy. The primary results were promising (*Hogeman & Willmar*, 1967), and it was therefore decided to evaluate the method by a critical analysis of a sufficiently large series of patients treated in a similar manner. The indications for Le Fort I osteotomy were gradually widened to include patients with maxillo-facial deformity with or without dental malocclusion.

During a 9 year period, 106 consecutive patients have been operated and examined at regular intervals up to three years postoperatively. Such a follow-up study was considered all the more urgent, as to the present day, no scientific analysis of dental occlusion, maxillary position and facial morphology after operation has been published.

The aim of the present study was to investigate the effects of Le Fort I osteotomy from the following aspects:

1. Soft tissue and bone healing, including complications.
2. Dental occlusion and maxillary position after surgery.
3. Facial morphology before and after surgery.

ANATOMICAL REMARKS

It is implied that the anatomy of the upper jaw is generally well known and for that reason only those anatomical structures of particular interest to the surgical procedure are mentioned. The osteotomy of Le Fort I type includes the medial, anterior and lateral walls of the maxillary sinus and the nasal septum. In addition, the maxillary tuberosity and the pterygoid process are separated. On the medial aspect of the tuberosity runs the pterygopalatine canal which opens into the major palatine foramen. This opening is located medially and anteriorly to the area of contact between the

maxillary tuberosity and the pterygoid process. The canal contains the descending palatine artery, vein and nerve.

The arteries supplying the lower part of the maxillary bone, the teeth and soft tissues are 4 branches of the maxillary artery with anastomoses to the facial artery.

1. The superior posterior alveolar artery enters the maxillary tuberosity to reach the molars, premolars, alveolar bone and the adjoining gingiva (Fig. 1).

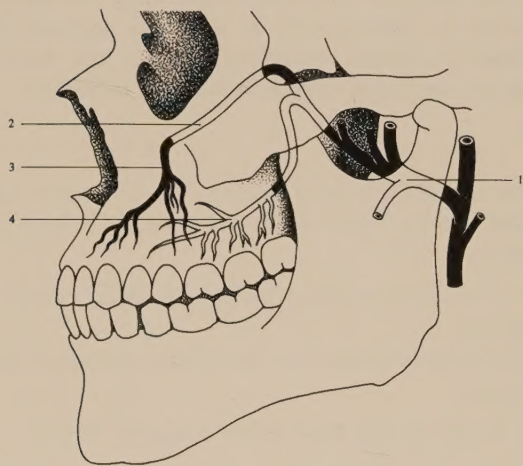


Fig. 1. Diagram of the arterial supply of the maxillary teeth.

1. Maxillary artery (A. maxillaris)
2. Infraorbital artery (A. infraorbitalis)
3. Anterior superior alveolar arteries (Aa. alveolares superiores anteriores)
4. Posterior superior alveolar arteries (Aa. alveolares superiores posteriores)

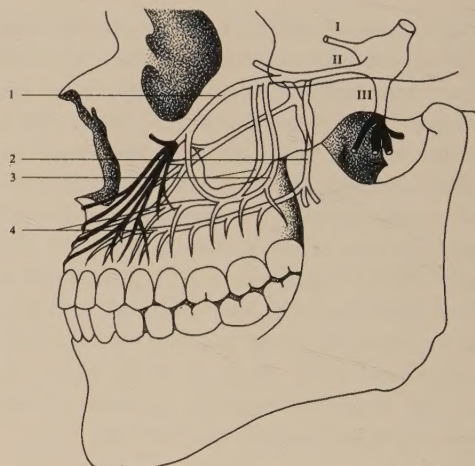


Fig. 2. Diagram of innervation of the maxillary teeth.

1. Infraorbital nerve. (N. infraorbitalis)
2. Palatine nerves (Nn. palatini major et minores)
3. Posterior superior alveolar nerves (R. alveolares superiores posteriores)
4. Anterior superior alveolar nerves (R. alveolares superiores anteriores)

2. The infraorbital artery runs through its canal in the orbital floor and gives off branches through the bone to the front teeth, canines, premolars, alveolar bone and adjacent gingiva. Several branches anastomose with posterior alveolar arteries. Emerging through the infraorbital foramen, the artery supplies the anterior part of the cheek and base of the upper lip and anastomoses with branches from the facial artery.

3. The descending palatine artery traverses the pterygopalatine canal, giving minor branches to the soft palate which anastomose with branches of the ascending palatine from the facial artery. The main branch emerging through the major palatine foramen supplies the mucous membrane and glands of the hard palate and the adjoining gingiva, where anastomoses exist with the gingival branches of the superior alveolar arteries.

4. The sphenopalatine artery enters the nasal cavity from above and supplies its walls and the maxillary sinus. A major branch along the base of the nasal septum descends through the incisal canal to anastomose with the terminal branches of the descending palatine artery.

Venous blood from the region just described returns through vessels which mainly accompany the arteries. From the pterygoid plexus in the infratemporal fossa, venous blood is emptied via the retromandibular and the facial veins.

Sensory innervation of the lower part of the maxilla and the nasal cavities is conveyed by the maxillary nerve, the middle branch of the trigeminal. The nerve, which is accompanied by postganglionic fibers from the sphenopalatine ganglion, enters the pterygopalatine fossa, where several branches are dispersed. The course of these branches show

great resemblance to the distribution of the final branches of the maxillary artery (Fig. 2).

There are three muscle pairs of interest, namely the buccinator, the tensor veli palatini and the levator veli palatini. The buccinator has one attachment on the posterior maxilla and is part of a semicircular system of muscle fibers that can be followed from the midline of the upper and lower lips to the pterygomandibular raphe. The tensor veli palatini muscle arises from the greater wing of the sphenoid bone and spreads out in the soft palate. The levator veli palatini muscle is attached to the petrosal bone and passes downwards into the soft palate.

In reviewing the anatomical details, the following points of importance should be given attention when performing Le Fort I osteotomy.

a. The osteotomy should be placed at least 4–5 mm above the level of the nasal floor to avoid injury to the apices of the teeth.

b. The well developed system of anastomoses between the branches of maxillary and facial arteries makes it possible to uncover the anterior and lateral aspects of the upper jaw, detach it and change its position without negative effects on the vascular supply of the maxilla. Furthermore, the course of the pterygopalatine canal with its vessels and nerves medially and anteriorly to the pterygomaxillary junction, will protect the descending palatine artery from injury when separating the process.

c. The innervation of the teeth in the upper jaw through the anterior and posterior alveolar rami will be impaired temporarily but reinnervation will occur.

HISTORICAL BACKGROUND

The first osteotomy of a Le Fort I type to correct dental malocclusion was performed by *Wassmund* (1927) on a patient with open bite. The osteotomy included the antero-lateral walls of the maxillary sinus bilaterally but only the anterior part of the medial walls and the base of the nasal septum. After one week of elastic traction the occlusion was normal, but the elastic intermaxillary fixation was continued 13 weeks until the maxilla was firmly united.

Axhausen (1934) was the first to mobilize and advance a malunited maxillary fracture by a Le Fort I osteotomy. His assistant *Steinkamm* reported in 1938 successful results of this type of operation in 2 patients with malunited maxillary fracture and one adult with bilateral cleft lip and palate.

Schuchardt (1942) described a two stage procedure with a Le Fort I type osteotomy of the maxilla as the first operation and, after a short period of overhead traction on the upper jaw, separation of the pterygoid processes from the maxillary tuberosities in the second operation. *Dingman & Harding* (1951) were the first to include separation of the pterygoid process from the maxillary tuberosity in combination with a Le Fort I osteotomy, later also described by *Obwegeser* (1965), *Antoni et al.* (1965) and others.

Transection of the pterygoid processes with the Le Fort I osteotomy was described by *Moore & Ward* (1949). *Ullik* (1970) strongly recommended osteotomy of the pterygoid processes with a Le Fort I operation in adult patients with operated cleft lip and palate. By including the pterygoid process in the osteotomy the surface of fractured bone was enlarged, thus promoting bony healing.

A particular type of operation was described by *Converse & Shapiro* (1952) with mobilization only

of the dento-alveolar part of the upper jaw. A similar type of operation has later been described by *Cupar* (1954), *Köle* (1963), *Mohnac* (1967) and *Paul* (1969).

The use of bone grafts to the osteotomy sites to promote healing was first reported by *Gillies & Rowe* (1954) and *Cupar* (1954), *Cernéa et al.* (1955) and *Lévignac* (1958). *Obwegeser* (1969) introduced the method of inserting a piece of bone in the gap formed by separation of the pterygoid process from the maxillary tuberosity to further stabilize the mobilized maxilla in its new position.

The methods of fixation of the mobilized maxilla to the cranium have gradually been developed from elastic bandage (*Converse & Shapiro*, 1952) or combined intra-extraoral appliances to a head cap (*Cernéa et al.*, 1955) to suspension wires round the zygomatic arches, primarily used in the treatment of maxillary fractures (*Adams*, 1942, *Hogeman*, 1956). The time of intermaxillary and inter-skeletal fixation varied from 10 to 12 weeks in earlier operated patients (*Hogeman & Willmar*, 1967); but, when bone grafts were introduced to the osteotomy sites with transosseous wires, the fixation period could be reduced to 3 to 6 weeks (*Obwegeser*, 1967, *Kiehn et al.*, 1968, *Willmar et al.*, 1973).

Very little has been reported on complications of this type of surgery. *Perko* (1972) investigated the frequency of sinusitis in 121 patients operated with Le Fort I or Le Fort III osteotomy. Only 5 patients (1.6%) demonstrated symptoms of sinusitis, which did not differ significantly from the incidence of sinusitis following mid-facial fractures. *Perko*, as well as *Widmaier* (1960), *Kiehn et al.* (1968) and *Kufner* (1971) reported a rapid return of the sensibility of the teeth in the upper jaw after Le Fort I osteotomy, i.e. 2–7 months. *Kiehn et al.* (1968) observed loss of 3 teeth in two patients with

cleft lip and palate after Le Fort I osteotomy and *Kufner* (1971) reported on loss of one tooth in his series of 48 patients operated with Le Fort I osteotomy. *Kufner* also noted infection in 3 patients, including an infraorbital abscess in one and loss of bone grafts in another. Furthermore, in 2 patients he found partial relapse and in 2 others complete relapse of the occlusion towards the preoperative state. Unfortunately, there is no scientific data on follow-up examinations of his operated patients.

In a thesis, *de Haller* (1969) presented a follow-up study of 34 patients, the majority operated with Le Fort I and some few with Le Fort III osteotomy (the number of each was not given). All patients were followed 3.5 months and 21 up to 16 months. An overall tendency to posterior change of maxillary position was found at follow-up.

In conclusion, the literature is thus far void of any scientific evaluation of follow-up results on a large series of patients with Le Fort I osteotomy.

MATERIAL AND METHODS

MATERIAL

Between March 1964 and March 1973, 98 patients were treated surgically and dental-orthopaedically with Le Fort I osteotomy, and 8 additional patients with splitting of the mandibular rami in the same sitting. These 8 patients were included at the study to elucidate the influence of the lower jaw during fixation period (cf. p. 36). The aims of Le Fort I osteotomy have been to correct dental malocclusion and to improve facial harmony.

Furthermore, the indication for simultaneous mandibular osteotomy in 8 patients was to adjust a protruding lower jaw. All patients were treated by one dental specialist (K. Willmar) and operated by one surgeon (K.-E. Hogeman)

Distribution of the patients in relation to age and sex is presented in table 1. The majority of patients were 20 to 39 years of age at time of operation, the youngest 16 and the oldest 58. Mean age of males and females was 27 and 25 years, respectively.

PATIENT GROUPS

The patients represented different degrees of maxillary deformity with or without malocclusion. 98 patients had anterior crossbite and 8 a maldeveloped upper jaw without dental malocclusion.

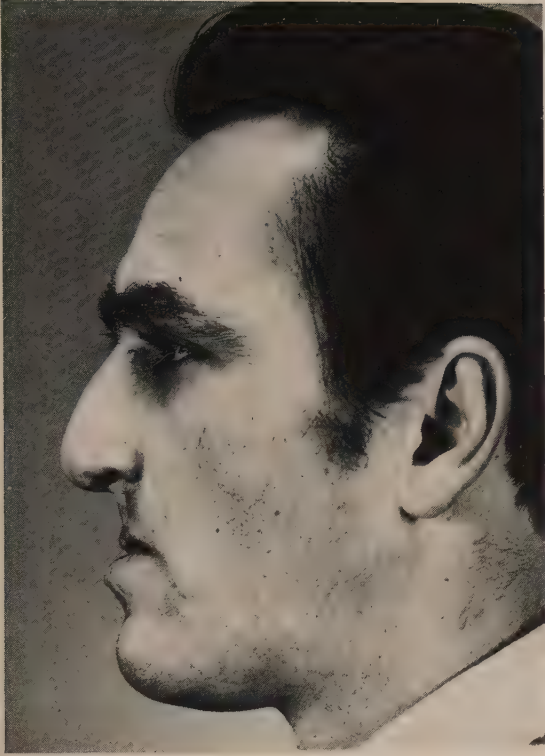
On the basis of clinical and morphological studies and the etiology of the malformations the patients were separated into four groups:

1. Cleft lip and palate
2. Idiopathic and post-traumatic anterior crossbite
3. Idiopathic short face
4. Idiopathic long face

TABLE 1.

Age and sex distribution of the patients

AGE	MALE	FEMALE	TOTAL
< 20	15	15	30
20-29	26	19	45
30-39	10	6	16
40-49	8	3	11
≥ 50	3	1	4
	62	44	106



1. *Cleft lip and palate* This group consisted of 17 males, mean age 25, and 8 females, mean age 32, earlier operated on the lip and palate. Unilateral deformity was present in 11 males and 6 females, whereas 6 males and 2 females had bilateral cleft lip and palate. All patients exhibited underdevelopment and retrusion of the maxilla with dental malocclusion. The morphology is described on page 42.



2. *Idiopathic and post-traumatic anterior crossbite* Patients in this group were characterized by dish face deformity and anterior crossbite with or without open bite. In 40 males, mean age 28, and 27 females, mean age 23, the etiology of the deformity was unknown (idiopathic). A history of maxillary fracture with malunion was present in 5 males, mean age 39, and 1 female, age 16 (post-traumatic). The morphology is described on page 43.

3. *Idiopathic short face* This group consisted of 5 females, mean age 19, with unusually low face height and prominent mandibular angles. When speaking and smiling the upper front teeth were covered by a normal lip, resulting in an edentulous appearance. When the mandible was held in habitual position, the free-way space was found to be more than 10 mm. The morphology is described on page 45.



4. *Idiopathic long face* Three female patients, mean age 30, with long face height exhibited an abnormal display of upper gingiva when smiling; they could close the lips only with difficulty (incompetent lips) and the mouth was habitually open. The morphology is described on page 45.



EXAMINATION OF THE PATIENT

All patients were referred to the maxillo-facial department because of complaints of dental malocclusion and/or facial disfigurement. The following examinations were made in order to ascertain the cause of these abnormalities.

1. Inquiry into the patient's general history, physical and mental state of health and motivation for treatment.

2. Examination of the face in full view and in profile with particular reference to harmony between the lips and nose and the position of the upper and lower jaws in relation to the facial midline. Attention was given to the length of the upper lip relative to the incisal edges of the upper front teeth as well as the movement of the lips when speaking and smiling.

3. Intraoral examination included the dental occlusion and the state of dentition, periodontal tissues and oral mucosa. Impressions were taken for study models.

4. Standardized radiographic examination of the skull, facial skeleton in full view and in profile and the dentition was done at The Department of Diagnostic Radiology, School of Dentistry, Malmö.

Since the aim of treatment was to obtain satisfactory dental occlusion as well as to create overall harmony of the face, the selection of patients was primarily based on analysis of dental casts and standardized profile radiographs.

- a. Analysis of dental casts concerned shifting the upper jaw into the best possible relationship with the lower jaw regarding overjet, overbite and intercuspitation.

- b. On the basis of standardized profile radiographs the position of the maxilla in relation to the anterior cranial base was compared with measurements from a reference group of 145 male and 172 female Swedish students, aged 19 to 23 years (Sarnäs, 1973). Complementary studies were done with standardized anterior-posterior radiographs of the maxilla in relation to the facial mid-

line. Transparent templates of the maxilla and the mandible were sometimes used to investigate the effect of shifting of one or both jaws on the profile outline.

PREOPERATIVE MEASURES

The results of these investigations were studied together with the clinical examination of the face and in all patients a maldeveloped and/or malposed upper jaw indicated surgical correction by Le Fort I osteotomy.

1. Analysis of dental casts in planning the desired occlusion demonstrated the necessity of re-shaping the dental arch in many patients. All together 58 patients had preoperative orthodontic treatment.

2. Grinding of teeth had to be done according to determinations made on study models in order to obtain best possible dental occlusion and locking of the bite.

3. Three types of fixation appliances were used. In patients with cleft lip and palate and in other malformations where the dental arch had to be altered a vitallium skeletal fixation appliance was utilized, constructed from a remodeled cast (Fig. 3). In the majority of patients, where congruity existed between the dental arches, labial arch bars were used. Fixation prostheses to the upper and/or lower jaw were used in edentulous patients.

4. In order to analyze the vitality of the teeth preoperatively and to confirm the reinnervation of the upper teeth at follow-up, electrical excitation was done in the conventional manner with a Bofors pulp tester. Pain reaction on exposure to an electric current of less than 125 microampères was accepted as a normal sensibility reaction.

5. Metal indicators according to the method of Björk (1955), were inserted in the right side of the upper jaw preoperatively close to the midline and in the molar region to increase the accuracy of postoperative analysis of the maxillary position. An additional standardized radiographic examination was then performed prior to operation.

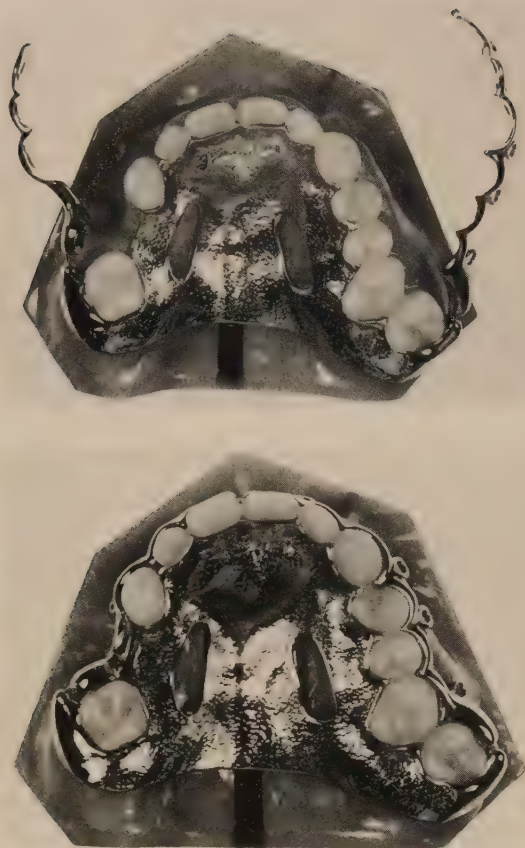


Fig. 3. The vitallium fixation appliance used in patients with cleft lip and palate and other dental arch malformations.

METHODS OF INVESTIGATION

In order to evaluate the results of operation as regards the position of the maxilla, two separate investigations were done, *i.e.* measurements on dental casts and examination of the maxillary position on profile radiographs using the metallic implants.

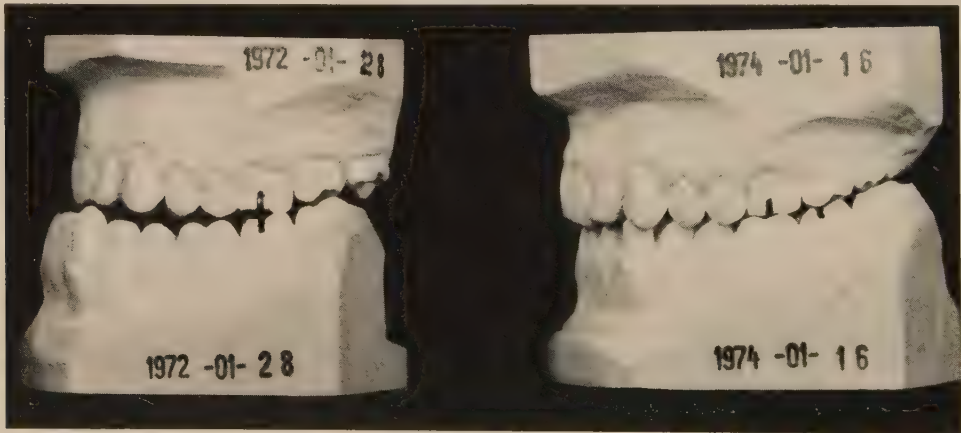
TABLE 2.

Time of investigations of dental casts, radiographs and electrical excitation of teeth.

Time	Dental casts	Radio-graphs	Excitation of tteth
Preoperatively	×	×	×
Immediately post op		×	
Before fixation removal		×	
After fixation removal	×		×
1 year	×	×	×
3 year	×	×	×

Dental casts

Analysis of dental casts required identification of set measuring points which could be reproduced before and after operation. The sagittal relations between the upper and lower molars or premolars were measured as shown in fig. 4. The width of the dental arch was measured as the minimum distance at the level of the gingival margin at the inter-molar and inter-canine positions (Fig. 5).



Anterior crossbite preoperatively

Normal dental occlusion postoperatively

Fig. 4. Analysis of sagittal molar relationship.

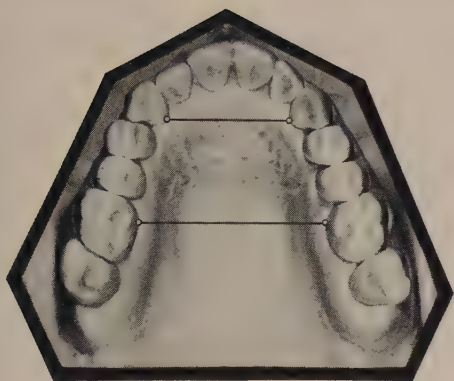


Fig. 5. The width of the dental arch measured at the level of the gingival margin at the inter-molar and inter-canine position (the minimum distance).

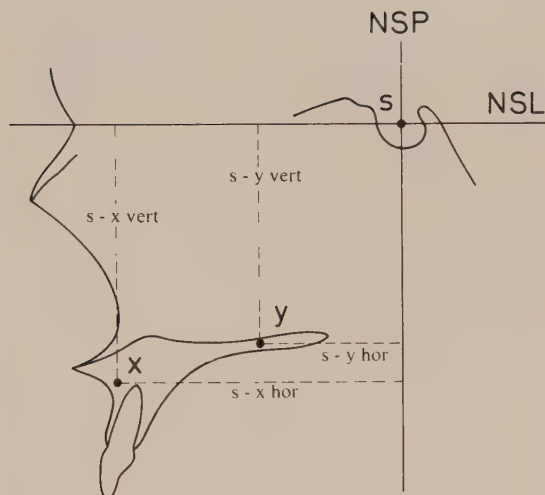


Fig. 6. Horizontal and vertical reference lines of points X and Y.

Radiographs

Standardized profile radiographs were obtained with the mandible in habitual occlusal position and with the mouth wide open, the left side of the face towards the film. Distances between x-ray anode and the midsagittal plane (MSP) of the head and between the MSP and the film were 155 cm and 10 cm, respectively. These distances were kept constant for each patient, giving a roughly 6 per cent enlargement of the image in the MSP.

Reference points and lines are situated in the midsagittal plane (MSP) or projections in this plane. Measurements were made directly on the radiographs (Björk & Solow, 1962) to the nearest 1/2 mm (0.5) and 1/2 grade (0.5) on two occasions in each patient, without correction for linear enlargement.

The position of the maxilla, pre- and postoperatively, was studied as follows: The anterior and posterior metal indicators were denoted X and Y, respectively, and studied in relation to a coordinate system composed by the axes NSL and NSP (Lindgård, 1953 and others). In this way the following measurements were obtained: $s-x$ hor, $s-x$ vert, $s-y$ hor and $s-y$ vert (Fig. 6).

STATISTICAL METHODS

Notations and formulas:

$$\begin{aligned} m &= \text{arithmetic mean} & \frac{\sum x}{n} \\ s &= \text{standard deviation} & \sqrt{\frac{\sum (x - m)^2}{n - 1}} \\ s^2 &= \text{variance} & \frac{\sum (x - m)^2}{n - 1} \\ s_{(i)} &= \text{error of method} & \sqrt{\frac{\sum (x_A - x_B)^2}{2n}} \end{aligned}$$

where x is the observed value, x_A and x_B represent double determinations, and n the number of observations.

d = changes in maxillary position, given as mean differences between consecutive measurements in each individual.

Comparisons of means have been based on Student's t -distribution, where

$$t = \frac{\text{difference}}{\text{standard error of difference}}$$

For intraindividual measurements, the method of paired comparisons was used. To compare the mean of two unpaired groups (own with Sarnäs' and Dahl's material), the variances were first analysed with an F -test. Variances were considered

equal (homogenous) if they did not differ significantly at the 2.5% level. The t-value was then calculated according to the formula :

$$t = \frac{m_1 - m_2}{s \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad s = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}$$

In the case of demonstrated unequal variances, the t-value was calculated from :

$$t = \frac{m_1 - m_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

This quantity is approximately distributed according to a t-distribution with f degrees of freedom, where f can be calculated from (Hald 1952, p. 398):

$$f = \frac{c^2}{\frac{c^2}{n_1 - 1} + \frac{(1 - c)^2}{n_2 - 1}}$$
$$c = \frac{s_1^2 n_1}{s_1^2 n_1 + s_2^2 n_2}$$

The following probability levels have been used in this study:

- * P < 0.05
- ** P < 0.01
- *** P < 0.001

In this study a difference is considered to be significant if P < 0.01.

ERROR OF THE METHODS

The error of the methods, *i.e.* the variation in repeated observations or precision (Hallert, 1967), was assessed in the following way.

Dental casts

The error of the measurements on the dental casts was determined on two separate sets of casts from each of 20 patients, selected by random, and the results are presented in table 3.

TABLE 3.

Precision, S_(i) for double determinations of dental dimensions on casts obtained at two different occasions in 20 patients.

Measurements	S _(i)
Sagittal molar- relationship	Left .18
	Right .23
Inter-canine width	.18
Inter-molar width	.12

Radiographs

Twenty (20) patients, randomly chosen, were each examined radiographically on two different occasions under conditions identical to that used in all patients, the only difference being the placement of the patient in the cephalostat. The results of the differences in measurements are presented in table 4.

TABLE 4.

Precision, S_(i) for double determinations of skeletal dimensions on radiographs obtained at two different examinations in 20 patients.

Measurements	S _(i)
s - x hor	.57
s - x vert	.35
s - y hor	.54
s - y vert	.32

SURGICAL PROCEDURE

(in collaboration with K.-E. Hogeman, M.D., Department of Plastic Surgery).

On admission to the department of plastic surgery, complete history and physical examination was done plus blood cell count, blood-typing, bleeding and coagulation time, E.S.R., Au-antigen determination, serum Na, K, urea and creatinine and standard urine analysis. Certain liver function tests were also performed since general anaesthesia with fluothane and hypotension were used (serum glutamic-oxaloacetic transaminase, glutamic-pyruvic transaminase, γ-glutamyl-transpeptidase, alkaline phosphatase and bilirubin).

The surgical technique of Le Fort I osteotomy has been gradually developed with increasing experience. The maxillary osteotomy in the first 43 patients included the pterygoid process, followed often by severe bleeding which required transfusion during the procedure. Aspiration of blood during operation in one patient with intermaxillary fixation necessitated tracheotomy. After this experience, preoperative tracheotomy was performed in 36 consecutive patients.

Although intravenous injection of epsilon-amino-caproic acid (EACA) 20 minutes before operation

was found to diminish bleeding considerably, it was not until hypotensive anaesthesia was introduced that tracheotomy could be eliminated.

The fatal course in one patient with an extremely short and maldeveloped maxilla (cf. p. 19) induced us to separate the pterygoid process from the maxillary tuberosity rather than to perform its transection. Finally, the delay of bony union for more than one year in a patient with extreme ante-positioning of the maxilla stimulated the routine use of bone grafts and transosseous wiring at the osteotomy sites.

The surgical technique thus developed has been applied to the last 41 patients of the present series. Endotracheal anaesthesia is induced via a cuffed nasotracheal tube. The lower part of the maxilla is first uncovered by a horizontal trans-mucosal incision extending posteriorly to the zygomatico-maxillary process. The anterior nasal spine and the base of the nasal septum are section-

ed submucously with a special osteotome, as are the medial walls of the maxillary sinuses. A low transverse osteotomy is then made with a pneumatic saw extending from the lateral borders of the piriform aperture through the anterior and lateral walls of the maxillary sinuses, the zygomatico-maxillary processes and the maxillary tuberosities. This osteotomy is placed at a level approximately 4–5 mm above the floor of the nose. Finally, the maxillary tuberosity is separated from the pterygoid process with a specially designed osteotome.

The maxilla can now be mobilized and brought into the planned occlusal position, where it is fixed by intermaxillary ligatures. Transalveolar wires are regularly applied to anchor maxillary fixation appliances. Pieces of cancellous bone from the iliac crest are placed over the osteotomy sites and fixed with osteosutures (Fig. 7, 8). In patients with operated cleft lip and palate, correction of the width of the dental arch is done after the surgical mobilization of the upper jaw



Fig. 7. Le Fort I osteotomy with bone grafts and osteosutures.

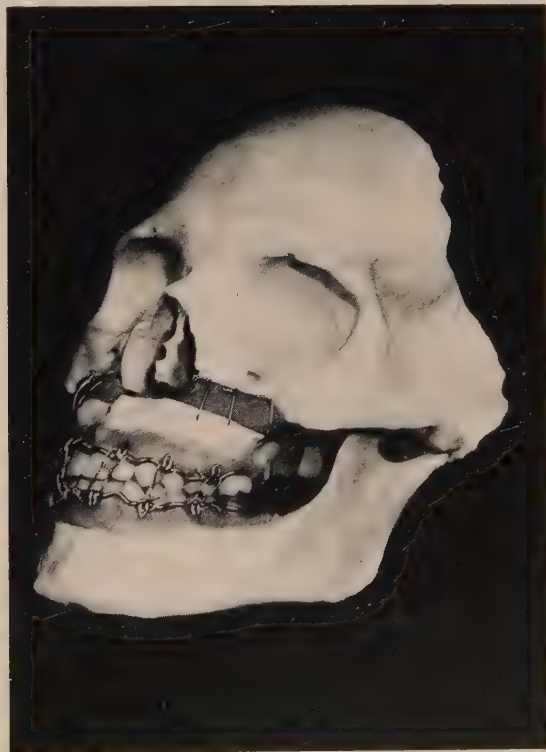


Fig. 8. Le Fort I osteotomy with bone grafts and osteosutures.

TABLE 5.
Type of anaesthesia and method of interskeletal fixation.

	No bone grafts n = 65	Bone grafts n = 33	Bone grafts and mand. splitting n = 8
<i>Type of anaesthesia</i>			
Intratracheal via nasal tube	10		
Intratracheal via tracheotomy	36		
Intratracheal via nasal tube and hypotension	19	33	8
<i>Method of interskeletal fixation</i>			
Suspension wires to zygomatic arches	65	10	
Suspension wires to zygomatic arches and osteosutures		20	8
Osteosutures		3	

and bone grafts are placed to bridge the cleft. Dice-shaped pieces of cancellous bone are placed between the pterygoid processes and the maxillary tuberosities to promote fixation and bony union. Suspension wires to the zygomatic arches are applied for further immobilization of the maxilla in patients with thin and fragile bone and when both jaws are corrected simultaneously.

All patients are cared for in the intensive care unit for 24–48 hours following operation.

POSTOPERATIVE CARE

Hospital care Patients with cleft lip and palate spent, on the average, 15 days (10 to 22) as inpatients; the others, 13 days (5 to 24). The duration of hospitalization did not vary with sex. One woman was not included in this analysis because she had an unusual complication requiring much longer hospitalization (see Complications, p. 19). Systemic antibiotics were routinely given. During the first 3 days postoperatively, patients were maintained with balanced intravenous fluids

plus supplemental feedings via naso-gastric tube. Thereafter, intravenous support was deleted and soft food was permitted orally. Healing and fixation were checked daily and a high standard of oral hygiene was maintained.

Out-patient care Patients from Malmö and its suburbs were seen twice weekly during the period of fixation at the maxillo-facial department of the hospital. Patients living further away were supervised by local dentists and every second week were also examined at the maxillo-facial department. At these visits, the intermaxillary fixation was checked and good oral hygiene was ensured. Because of minor infection around the internal wires, eight patients were treated with systemic antibiotics.

The fixation period varied between 5 and 12 weeks. Immediately after operation and before removal of the fixation appliance, the patients were examined radiographically to check the fixation wires and position of the maxilla.

After the fixation period, patients were examined every second month until sensibility returned to the upper lip, teeth and soft tissues of the maxilla.

RESULTS

SOFT TISSUE AND BONE HEALING

Healing of the mucoperiosteal incision was uneventful except in one patient (see Complications p. 19). Sensibility for pain in the gingiva and mucosa of the upper lip and palate was tested by reaction to pinprick.

Bony union was assessed clinically by manually testing the stability of the upper jaw after removal of the fixation appliance. In patients without bone grafts to the osteotomy sites, stability was usually attained within 12 weeks. One exception was a male patient with idiopathic anterior crossbite in whom the maxilla was shifted 17 mm anteriorly and where stability could not be demonstrated until 3 years after operation. During this period of nonunion, however, no demonstrable change was recorded in the position of the maxilla. The marked antepositioning of the maxilla without the use of bone grafts and osteosutures seemed to be responsible for the delay of bony union in this case. Forty-one other patients, in whom bone grafts and osteosutures were applied to the osteotomy sites, demonstrated bony union within 5–6 weeks. No untoward reactions were observed in the maxillary sinuses either clinically or radiographically at the 1 and 3 year follow-ups.

In 4 of the 92 patients examined 1 year after operation, 9 teeth which had reacted positively before operation were found to have lost their sensibility. Four of these teeth (upper left premolars and molars) were those of the 20 year old female reported below. One of the four patients demonstrated at the 3 year follow-up two teeth with loss of sensibility but without discoloration.

COMPLICATIONS

The only serious complication ascribable to the surgical operation occurred in a 54 year old man with bilateral cleft lip and palate. In previous

operations the lip had been repaired and for prosthodontic reasons he was now admitted for correction of the position of the maxilla associated with a wide unoperated palatal cleft. The maxilla was found to be extremely underdeveloped, retracted and edentulous. At operation, the maxillary bone was found to be very sclerotic and caused troublesome technical difficulties, but the maxilla was finally mobilized and fixed in the planned position. The patient, however, did not recover consciousness following operation and demonstrated symptoms of left-sided hemiplegia. He was transferred to the neurosurgical department, where he died the following day. Post-mortem examination revealed morphological anomalies of the skull, and it was noted that the portion of the cranial base encompassing the right middle fossa protruded abnormally inferiorly and anteriorly. It closely approached the posterior aspect of the maxilla and was unintentionally fractured during the maxillary osteotomy. The anomaly was further evident from the measurements on the profile radiograph where *s-pm hor* was 4.5 mm and *s-pm vert* 44.0 mm and from the total absence of teeth and alveolar ridges posteriorly. A similar case, though not fatal, has been described by Ullik (1970).

In a 20 year old female with unilateral cleft lip and palate, bone grafts were placed at the osteotomy sites and at the bony cleft. Postoperatively, a portion of the buccal gingiva on the smaller segment became cyanotic, then underwent necrosis with a subsequent loss of soft tissue. The palatal mucosa, however, showed no signs of disturbed circulation and the interdental papillae were intact. The buccal defect was repaired with a mucosal flap, and at the one year follow-up the alveolar process was well covered. Half a year postoperatively, a piece of necrotic bone was extracted from the nasal floor. One year later another bone sequestrum and a transosseous wire were removed from the same

area with subsequent healing. The smaller alveolar segment had also since relapsed, but orthodontic treatment was undertaken and the dental arch was normalized.

POSITION OF MAXILLA

To study the postoperative position of the maxilla, analysis was made of the relationship between the jaws on dental casts prepared at removal of the fixation appliance (After fix. rem.) and at the 1 and 3 year follow-ups. Furthermore, maxillary position in relation to the anterior cranial base was examined on profile radiographs with the aid of the metallic implants, X and Y. These investigations were performed within a week after surgery (Imm. post op.), immediately before removal of the fixation appliance (Before fix. rem.) and at the 1 and 3 year follow-ups. The distribution of patients at operation and at 1 and 3 year follow-ups is presented in table 6. Patients missing at the 1 year follow-up are presented in table 7.

The first and second radiographic examinations were used to study the shift in maxillary position following surgery and the stability of the intermaxillary and interskeletal fixation during the immobilization period. The changes in dental occlusion and width of the upper dental arch following operation were studied on dental casts

which could be produced only after removal of the fixation appliances.

The 1 year follow-up examination was chosen because at that time resolution of any residual surgical reactions should have occurred. After this examination, a longer period of follow-up was desired (*i.e.* 3 years) in order to investigate late changes in dental occlusion and position of the maxilla.

TABLE 6.
Distribution of patients at operation and at follow-up.

Patient groups	Operated patients	Follow up	
		1 year	3 years
Cleft lip and palate	♂ 17 ¹⁾	♂ 11	♂ 8
	♀ 8	♀ 7	♀ 6
Idiopathic and post-traumatic anterior crossbite	♂ 45	♂ 42	♂ 32
	♀ 28	♀ 25	♀ 16
Idiopathic short face	♀ 5	♀ 4	♀ 3
Idiopathic long face	♀ 3	♀ 3	0
Total	106	92	65

¹⁾ One patient expired after operation.

TABLE 7.
Patients missing at 1 the year follow-up.

	Cleft lip and palate	Idiopathic and posttraumatic ant. crossbite	Idiopathic short face	Idiopathic long face
Expired	♂ 1			
Refused to come	♂ 1	♂ 2 ♀ 2		
Less than 1 year after operation	♂ 4 ♀ 1	♂ 1 ♀ 1	♀ 1	
Total	7	6	1	

At the 3 year follow-up, 1 patient had expired from non-related causes.
In 26 patients, the postoperative period was less than 3 years.

ANALYSIS OF DENTAL CASTS

Only patients with preoperative dental malocclusion were studied, *i.e.* those with *cleft lip and palate* and *idiopathic and post-traumatic anterior cross-bite*. In edentulous patients and patients with teeth missing in the canine and molar regions or those having postoperative orthodontic or prosthodontic therapy, pre- and/or postoperative measurements had to be excluded (Tables 10, 12, 14).

Four male and four female patients with idiopathic anterior crossbite were analysed separately because the maxilla and mandible were mobilized at the same operation. These patients are accounted for in tables 15 and 16. The postoperative follow-up period was less than 3 years.

Cleft lip and palate

Measurements were not performed in these patients later than 1 year after operation because of additional prosthodontic and/or surgical treatment. Reasons for follow-up measurements not being performed are given in table 10.

Immediately after removal of fixation, the molar relationship was noted to have changed 5.8 mm in males and 4.8 mm in females. Significant secondary changes were not found at the 1 year follow-up (Table 8).

In both males and females, significant changes were not observed in the width of the upper dental arch at the time of fixation removal or at the 1 year follow-up examination (Table 9).

TABLE 8.

Cleft lip and palate, males and females. Differences in sagittal molar relationship presented as mean value of right and left side measurements $\frac{R + L}{2}$.

<i>Males</i>	n	d	Range	s	t
After fix.rem.	15	+5.78	+0.6—+9.3	2.41	9.26***
1 year	10	−0.70	−2.4—+0.8	1.74	1.27
<i>Females</i>					
After fix.rem.	7	+4.79	+2.2—+7.4	1.90	6.67***
1 year	5	−0.50	−1.9—+0.1	0.80	1.40

TABLE 9.

Cleft lip and palate, males and females. Differences in the width of the dental arch at the inter-canine and inter-molar regions.

Inter canine region.					
<i>Males</i>	n	d	Range	s	t
After fix.rem.	13	+0.54	−3.0—+6.0	2.35	0.83
1 year	9	+0.37	−0.4—+3.9	1.34	0.82
<i>Females</i>					
After fix.rem.	7	+2.41	−5.8—+4.9	5.34	1.20
1 year	5	+0.48	±0.0—+2.8	1.31	0.82
Inter molar region.					
<i>Males</i>	n	d	Range	s	t
After fix.rem.	14	−1.37	−9.4—+4.2	3.51	1.46
1 year	9	+0.63	−0.9—+5.8	1.98	0.96
<i>Females</i>					
After fix.rem.	7	+0.47	−7.0—+4.7	4.09	0.31
1 year	5	+0.06	−0.7—+1.0	0.61	0.22

TABLE 10.

Reasons for absence of follow-up measurements in males and females with *cleft lip and palate*.

Sagittal molar relationship				
	Males	Females		
<i>After fix. rem.</i>	(16)	(8)		
Full upper denture	1	1		
<i>1 year</i>	(11)	(7)		
Full upper denture	1	1		
Orthodontic treatment	—	1		
Inter-canine region			Inter-molar region	
	Males	Females	Males	Females
<i>After fix. rem.</i>	(16)	(8)	(16)	(8)
Full upper denture	1	1	1	1
Without teeth in reg.	2	—	1	—
<i>1 year</i>	(11)	(7)	(11)	(7)
Full upper denture	1	1	1	1
Without teeth in reg.	1	—	1	—
Orthodontic treatment	—	1	—	1

Idiopathic and post-traumatic anterior cross-bite
Measurements missing at follow-ups are accounted for in tables 12, 14.

Males The antepositioning of the upper jaw, measured at fixation removal, had altered the molar relationship by, on the average, 7.6 mm. At 1 year follow-up this shift had decreased by 0.6 mm.
No further change in the molar relationship was found at the 3 year follow-up. Good dental occlusion was obtained in all patients but one, where the upper dental arch collapsed resulting in

an edge to edge bite. Here, the preoperative orthodontic expansion could not be maintained due to the patient's lack of cooperation (Table 11).
Females Here, the forward shift of the upper jaw resulted in a mean change in the molar relationship of 5.3 mm. No significant changes were demonstrated at the 1 and 3 year follow-ups. All patients in this group demonstrated good dental occlusion (Table 11).
In both the male and female groups no significant changes were noted in the width of the upper dental arch at termination of fixation or at the 1 and 3 year follow-ups (Table 13).

TABLE 11.

Idiopathic and post-traumatic anterior crossbite, males and females. Differences in sagittal molar relationship presented as mean value of right and left side measurements $\frac{R + L}{2}$.

	n	d	Range	s	t
<i>Males</i>					
After fix.rem.	33	+ 7.62	+ 0.8 — + 16.2	3.34	13.11***
1 year	30	— 0.58	— 2.4 — + 0.8	0.79	4.00***
3 years	22	— 0.13	— 1.7 — + 0.6	0.27	2.32*
<i>Females</i>					
After fix.rem.	22	+ 5.38	+ 1.5 — + 11.6	2.87	8.78***
1 year	19	— 0.22	— 1.3 — + 0.7	0.63	1.53
3 years	12	+ 0.13	— 0.9 — + 1.7	0.66	0.66

TABLE 12.

Reasons for absence of follow-up measurements in males and females with *idiopathic and post-traumatic anterior crossbite*.

	Sagittal molar relationship	
	Males	Females
<i>After fix. rem.</i>	(41)	(24)
Full upper denture	8	2
<i>1 year</i>	(38)	(21)
Full upper denture	7	2
Orthodontic treatment	1	—
<i>3 years</i>	(32)	(16)
Full upper denture	6	1
Orthodontic treatment	1	1
Prosthetic treatment	2	1
Missing at 1 year	1	1

TABLE 13.

Idiopathic and post-traumatic anterior crossbite, males and females. Differences in width of the dental arch at the inter-canine and inter-molar regions.

Inter-canine region.					
<i>Males</i>	n	d	Range	s	t
After fix.rem.	29	+0.16	-2.3 - +1.9	0.82	1.04
1 year	26	-0.02	-1.0 - +0.8	0.35	0.33
3 years	21	-0.13	-1.0 - +0.7	0.34	1.81
<i>Females</i>					
After fix.rem.	20	+0.09	-1.2 - +1.8	0.69	0.62
1 year	18	-0.08	-0.8 - +0.7	0.33	1.11
3 years	12	-0.10	-1.0 - +1.4	0.69	0.50
Inter-molar region.					
<i>Males</i>					
After fix.rem.	30	+0.04	-3.0 - +1.8	1.33	0.16
1 year	28	-0.08	-2.6 - +0.7	1.78	0.39
3 years	22	-0.63	-2.1 - +0.4	2.17	1.36
<i>Females</i>					
After fix.rem.	20	+0.21	-1.0 - +1.1	0.97	0.96
1 year	18	-0.21	-1.0 - +0.4	0.39	2.29*
3 years	12	-0.31	-2.4 - +0.3	0.72	1.50

TABLE 14.

Reasons for absence of follow-up measurements in males and females with *idiopathic and post-traumatic anterior crossbite*.

	Inter-canine region.		Inter-molar region.	
	Males (41)	Females (24)	Males (41)	Females (24)
<i>After fix. rem.</i>				
Full upper denture	8	2	8	2
Without teeth in reg.	4	2	3	2
<i>1 year</i>	(38)	(21)	(38)	(21)
Full upper denture	7	2	7	2
Without teeth in reg.	4	1	2	1
Orthodontic treatment	1	—	1	—
<i>3 years</i>	(32)	(16)	(32)	(16)
Full upper denture	6	1	6	1
Without teeth in reg.	1	—	—	—
Orthodontic treatment	1	1	1	1
Prosthetic treatment	2	1	2	1
Missing at 1 year	1	1	1	1

Idiopathic anterior crossbite with bimaxillary mobilization

In all 8 patients (4 male and 4 female), the maxilla was shifted anteriorly and the mandible posteriorly during the same operation. The mean change in the molar relationship at fixation removal was an

anterior shift of 7.7 mm in males and 6.7 mm in females. No further secondary changes were observed at the 1 year follow-up in either group (Table 15). In both the male and female groups no significant changes were noted in the width of the upper dental arch (Table 16).

TABLE 15.

Idiopathic anterior crossbite with bimaxillary mobilization, males and females. Differences in sagittal molar relationship presented as mean value of right and left side measurements $\frac{R + L}{2}$.

	n	d	Range	s	t
<i>Males</i>					
After fix.rem.	4	+7.65	+4.2 — +9.4	2.45	6.24**
1 year	4	—0.67	—1.3 — +0.1	0.59	2.29
<i>Females</i>					
After fix.rem.	4	+6.68	+4.0 — +9.6	2.65	5.02*
1 year	4	+0.25	—0.5 — +1.3	0.75	0.66

TABLE 16.

Idiopathic anterior crossbite with bimaxillary mobilization, males and females. Differences in width of the dental arch at the inter-canine and inter-molar regions presented as mean values.

Inter-canine region.					
<i>Males</i>	n	d	Range	s	t
After fix.rem.	4	+0.43	-1.8 - +2.1	1.64	0.52
1 year	4	+0.45	±0.0 - +1.1	0.42	2.14
<i>Females</i>					
After fix.rem.	4	+0.28	±0.0 - +0.9	0.43	1.29
1 year	4	+0.25	-1.0 - ±0.0	0.50	1.00
Inter-molar region.					
<i>Males</i>					
After fix.rem.	4	+0.95	-1.1 - +5.6	3.13	0.61
1 year	4	+0.73	-0.1 - +2.2	1.06	1.36
<i>Females</i>					
After fix.rem.	4	+0.28	-0.4 - +0.8	0.57	0.96
1 year	4	-0.05	-0.3 - +0.5	0.33	0.30

CONCLUSION

In the *cleft lip and palate group*, neither males nor females demonstrated significant changes in the molar relationship from the time of removal of fixation appliances until the 1 year postoperative examination. This indicates that the mobilized maxilla did not move from its new location, *i.e.* good dental occlusion was permanently obtained.

Considering the *idiopathic and post-traumatic group*, an average relapse of 0.6 mm in the molar relationship had occurred from the time of removal of fixation until the 1 year follow-up in males, but this did not interfere with the dental occlusion. In the female patients, the dental occlusion remained stable throughout the follow-up period.

Eight patients with simultaneous splitting of the mandible demonstrated stable dental occlusion at the 1 year follow-up examination.

No significant changes were noted in the width of the upper dental arch.

ANALYSIS OF PROFILE RADIOGRAPHS

The mean changes of points X and Y at follow-up are also illustrated by schematic representations of the various groups. Horizontal changes of the maxilla postoperatively were determined by the position of point X, situated close to the midsagittal plane (MSP). Point Y was of less reliability because of the great distance to the MSP.

This analysis has been performed on 105 patients exhibiting a malposed and/or maldeveloped maxilla with or without malocclusion. Those with malocclusion have been divided into two main groups, *cleft lip and palate* and *idiopathic and post-traumatic anterior crossbite* (with or without open bite). Eight patients in the idiopathic group in whom an additional operation of the mandible (splitting) was performed at the same sitting, were studied separately. In this way the probable influence of the mandible on the mobilized maxilla could be elucidated.

The patients without malocclusion were denoted *idiopathic short* and *idiopathic long face*.

Cleft lip and palate

Males

Horizontal changes Point X was surgically mobilized, on the average, 6.0 mm anteriorly ($P < 0.001$). During the period of intermaxillary fixation, no change in the position of this point was observed. Within the following year, point X had moved 1.0 mm posteriorly ($P < 0.01$). No further significant change was found at the 3 year follow-up (Table 17).

TABLE 17.
Horizontal changes of point X

<i>s-x hor</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	15 ¹⁾	+5.97	+4.0 - +9.0	2.37	9.74***
Before fix.rem.	14 ¹⁾	+0.04	-2.0 - +1.5	0.82	0.16
1 year	10 ¹⁾	-0.95	-2.5 - +0.5	0.93	3.25**
3 years	8	-0.69	-2.5 - +0.5	1.03	1.88

¹⁾ 1 patient not included due to absence of radiographs.

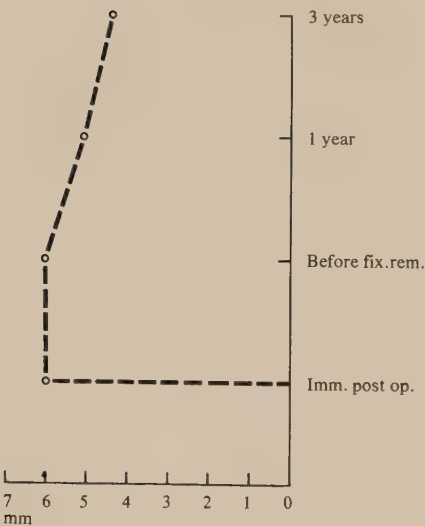


FIG. 9.
Cleft lip and palate, males. Horizontal changes in position of point X immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups. Reference point X — — —

Note: Time scale intentionally uncorrected.

Vertical changes Reference point X was moved 2.5 mm inferiorly as an immediate result of surgery. Similarly, reference point Y had moved 1.1 mm. During the period of immobilization, point X had moved superiorly 1.3 mm and point Y 1.0 mm ($P < 0.01$). No significant changes in the position of X and Y were seen at the 1 and 3 year follow-ups (Table 18).

TABLE 18.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	15 ¹⁾	+2.53	-3.0 - + 11.0	3.44	2.85*
Before fix.rem.	14 ¹⁾	-1.29	-4.5 - + 2.5	1.67	2.88*
1 year	10 ¹⁾	+0.65	-1.0 - + 4.5	1.55	1.33
3 years	8	-0.56	-2.5 - + 0.5	1.02	1.57
<i>s-y vert</i>					
Imm. post op.	15 ¹⁾	+1.13	-4.5 - + 5.5	2.51	1.75
Before fix.rem.	14 ¹⁾	-1.04	-3.0 - ± 0.0	0.94	4.08**
1 year	10 ¹⁾	+0.25	-0.5 - + 1.0	0.60	1.34
3 years	8	-0.50	-2.5 - + 0.5	0.96	1.47

¹⁾ 1 patient not included due to absence of radiographs.

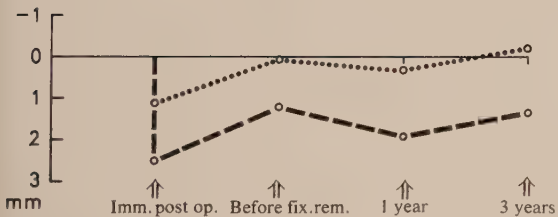


FIG. 10.

Cleft lip and palate, males. Vertical changes in position of points X and Y immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups.

Reference point X - - -

Reference point Y · · ·

Note: Time scale intentionally uncorrected.

Females

Horizontal changes It is noted that reference point X was moved, on the average, 4.1 mm anteriorly ($P < 0.01$). During the intermaxillary fixation period, no significant change in position was found, but at the 1 year follow-up, an average change of 1.0 mm had occurred in the posterior direction ($P < 0.01$). Later on, no further significant change could be demonstrated (Table 19).

TABLE 19.
Horizontal changes of point X

<i>s - x hor</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	8	+4.06	+1.5 - +8.0	3.08	3.74**
Before fix. rem.	8	+0.13	-1.0 - +0.5	0.64	0.55
1 year	7	-1.00	-1.5 - +0.0	0.71	3.74**
3 years	6	-0.17	-1.5 + +1.5	0.98	0.42

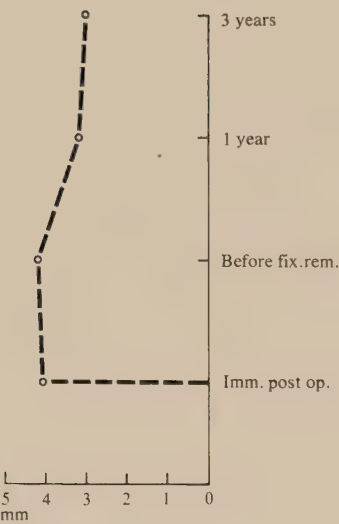


FIG. 11.
Cleft lip and palate, females. Horizontal changes in position of point X immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups. Reference point X - - -

Note: Time scale intentionally uncorrected.

Vertical changes Neither point X nor point Y had significantly changed position immediately after surgery. Following the intermaxillary fixation period, points X and Y had shifted their positions insignificantly in a superior direction 2.3 mm and 1.9 mm, respectively. At the 1 and 3 year follow-ups no significant changes were recorded (Table 20).

TABLE 20.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	8	-0.25	-6.0 - +2.0	3.91	0.18
Before fix.rem.	8	-2.31	-6.5 - -0.5	1.89	3.46*
1 year	7	+0.29	-1.0 - +1.5	0.81	0.93
3 years	6	±0.00	-0.5 - +0.5	0.32	0.00

<i>s-y vert</i>	n	d	Range	s	t
Imm. post op.	8	+1.38	-4.0 - +6.5	3.83	1.01
Before fix.rem.	8	-1.88	-6.0 - ±0.0	1.79	2.97*
1 year	7	-0.57	-2.5 - +0.5	0.98	1.55
3 years	6	±0.00	-0.5 - +0.5	0.45	0.00

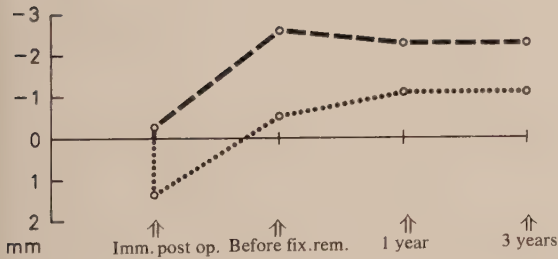


FIG. 12.
Cleft lip and palate, females. Vertical changes in position of point X and Y immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups.
Reference point X - - -
Reference point Y . . .

Note: Time scale intentionally uncorrected.

Idiopathic and post-traumatic anterior crossbite

Males

Horizontal changes An anterior shift in point X of 7.2 mm was surgically obtained ($P < 0.001$). During the period of immobilization and at follow-up 1 and 3 years after surgery, secondary changes in the position of this point were not significant (Table 21).

TABLE 21.
Horizontal changes of point X

$s-x$ hor	n	d	Range	s	t
Imm. post op.	39 ¹⁾	+7.21	+0.5 - +17.0	4.18	10.76***
Before fix.rem.	38 ²⁾	+0.12	-3.0 - + 2.5	1.39	0.53
1 year	38	-0.30	-3.5 - + 1.5	1.21	1.55
3 years	30 ¹⁾	-0.03	-2.0 - + 1.5	0.93	0.20

¹⁾ 2 patients }
²⁾ 1 patient } not included due to absence of radiographs.

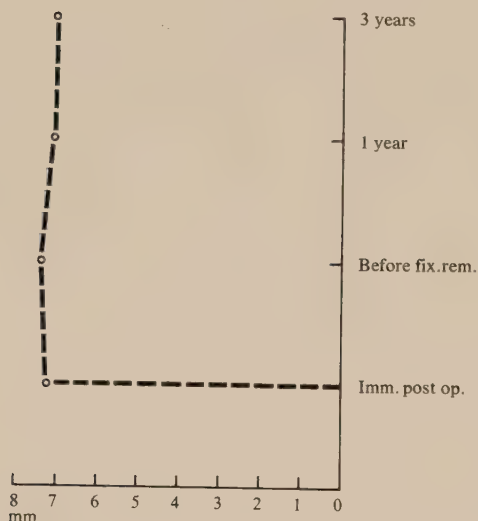


FIG. 13.

Idiopathic and post-traumatic anterior crossbite, males. Horizontal changes in position of point X immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups. Reference point X - - -

Note: Time scale intentionally uncorrected.

Vertical changes Points X and Y were surgically shifted inferiorly an average of 3.4 mm ($P < 0.001$) and 2.2 mm ($P < 0.001$), respectively. During the period of intermaxillary fixation, points X and Y both moved in a superior direction 1.8 mm ($P < 0.001$) and 0.8 mm ($P < 0.01$), respectively. At the 1 and 3 year follow-ups, no further significant changes in their position were found (Table 22).

TABLE 22.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	39 ¹⁾	+3.35	-5.0 - +11.0	3.34	6.26***
Before fix.rem.	38 ²⁾	-1.80	-7.0 - + 5.0	2.36	4.71***
1 year	38	+0.26	-3.5 - + 3.5	1.22	1.33
3 years	30 ¹⁾	-0.15	-1.0 - + 1.5	0.74	1.10

<i>s-y vert</i>	n	d	Range	s	t
Imm. post op.	39 ¹⁾	+2.23	-1.5 - +10.0	2.44	5.71***
Before fix.rem.	38 ²⁾	-0.83	-4.0 - + 3.0	1.47	3.47**
1 year	38	+0.25	-1.5 - + 3.0	1.10	1.41
3 years	30 ¹⁾	+0.05	-2.0 - + 1.5	0.80	0.34

¹⁾ 2 patients
²⁾ 1 patient

} not included due to absence of radiographs.

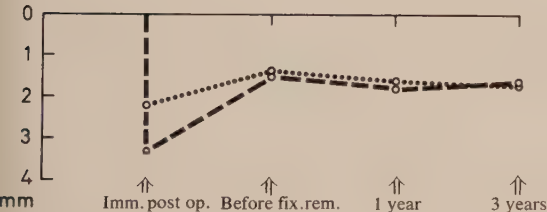


FIG. 14.
Idiopathic and post-traumatic anterior crossbite, males.
Vertical changes in position of point X and Y immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups.
Reference point X - - -
Reference point Y . . .

Note: Time scale intentionally uncorrected.

Females

Horizontal changes Here, point X had shifted its position anteriorly an average of 5.7 mm ($P < 0.001$). Following immobilization and at the 1 and 3 year follow-ups insignificant changes were observed (Table 23).

TABLE 23.
Horizontal changes of point X

<i>s - x hor</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	22 ¹⁾	+5.73	+0.5 - +14.0	3.59	7.47***
Before fix.rem.	21 ²⁾	+0.86	-2.0 - + 3.5	1.57	2.49*
1 year	20 ³⁾	-0.65	-3.0 - + 2.5	1.22	2.39*
3 years	15 ³⁾	-0.37	-1.0 - + 1.0	0.74	1.91

¹⁾ 2 patients
²⁾ 3 patients
³⁾ 1 patient

} not included due to absence of radiographs.

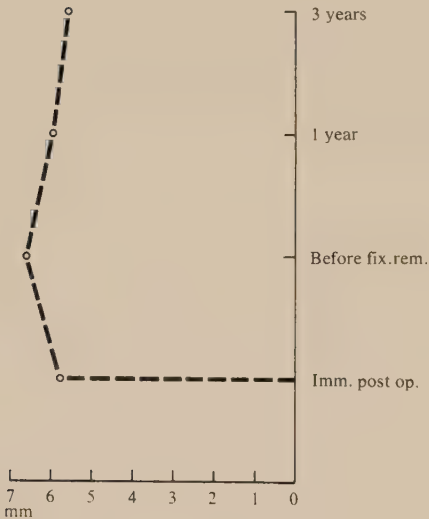


FIG. 15.
Idiopathic and post-traumatic anterior crossbite, females.
Horizontal changes in position of point X immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups. Reference point X - - -

Note: Time scale intentionally uncorrected.

Vertical changes It was found that the postoperative position of X and Y had changed inferiorly, on the average, 3.3 mm ($P < 0.001$) and 1.1 mm, respectively. During the immobilization period, a change in the superior direction of points X and Y had occurred, 2.3 mm ($P < 0.001$) and 1.1 mm ($P < 0.01$), respectively. Later examinations at 1 and 3 years did not reveal further significant changes (Table 24).

TABLE 24.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	22 ¹⁾	+3.30	-5.0 - +7.5	3.05	5.07***
Before fix.rem.	21 ²⁾	-2.31	-9.0 - ±0.0	2.11	5.02***
1 year	20 ³⁾	+0.25	-1.0 - +4.0	1.40	0.80
3 years	15 ³⁾	±0.00	-1.5 - +1.0	0.60	0.00

<i>s-y vert</i>	n	d	Range	s	t
Imm. post op.	22 ¹⁾	+1.14	-3.5 - +5.0	2.27	2.34*
Before fix.rem.	21 ²⁾	-1.14	-6.0 - -2.0	1.67	3.14**
1 year	20 ³⁾	+0.10	-3.0 - +4.5	1.42	0.31
3 years	15 ³⁾	+0.20	-0.5 - +1.0	0.36	2.10

1) 2 patients
2) 3 patients
3) 1 patient

} not included due to absence of radiographs.

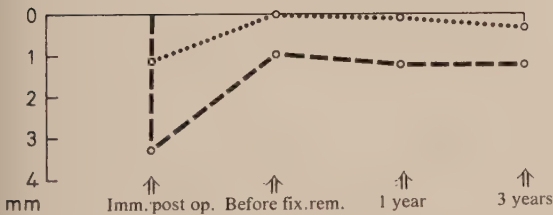


FIG. 16.
Idiopathic and post-traumatic anterior crossbite, females.
Vertical changes in position of points X and Y, immediately post op, at removal of fixation appliance and at the 1 and 3 year follow-ups.
Reference point X - - -
Reference point Y · · ·
Note: Time scale intentionally uncorrected.

Idiopathic short and long face

Surgical correction in these patients concerned mainly the superior-inferior position of the maxilla. Although it did not significantly affect the maxillo-mandibular relationship, the anterior-posterior position of the maxilla has been studied as well. Both horizontal and vertical changes are presented.

Idiopathic short face

Horizontal changes The mean posterior change of point X immediately after operation was due to the great inferior positioning of the maxilla with unchanged occlusion (Table 25).

TABLE 25.
Horizontal changes of point X

<i>s-x hor</i>	n	d	Range	s	t
Imm. post op.	5	-3.0	-4.5 - -1.0	1.54	4.35*
Before fix.rem.	5	+1.0	-1.0 - +3.0	1.45	1.53
1 year	4	-0.1	-0.5 - +1.0	0.75	0.33
3 years	3	-0.5	-1.5 - ±0.0	0.86	1.00

Vertical changes The average primary change of point X and Y inferiorly was 9.5 mm ($P<0.01$) and 3.2 mm, respectively. At the completion of the

intermaxillary fixation period, and at the 1 and 3 year follow-ups, no significant mean changes in the positions of X and Y were observed (Table 26).

TABLE 26.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	5	+9.50	+5.0 - +15.5	3.97	5.35**
Before fix.rem.	5	-1.60	-3.0 - ± 0.0	1.29	2.76
1 year	4	-0.50	-2.0 - + 1.0	1.22	0.81
3 years	3	±0.00	-1.0 - + 0.5	0.87	0.00

<i>s-y vert</i>	n	d	Range	s	t
Imm. post op.	5	+3.20	±0.0- + 6.0	2.13	3.35*
Before fix.rem.	5	-1.00	-2.0- ± 0.0	0.94	2.39
1 year	4	+0.88	±0.0- + 3.0	1.44	1.22
3 years	3	-0.17	-1.0- + 0.5	0.76	0.38

Idiopathic long face

Horizontal changes The average change of point X in anterior direction immediately after operation

was dependant on the superior positioning of the maxilla with unchanged occlusion (Table 27).

TABLE 27.
Horizontal changes of point X

<i>s-x hor</i>	n	d	Range	s	t
Imm. post op.	3	+5.17	+3.0 - +7.0	2.02	4.25
Before fix.rem.	3	+0.17	-0.5 - +1.0	0.76	0.38
1 year	3	-0.17	-1.0 - +0.5	0.76	0.38

Vertical changes The surgical change in position of X and Y in the superior direction was an average of 7.7 mm and 3.7 mm, respectively. During the

fixation period and at the 1 year follow-up, no significant changes in the positions of X and Y were found (Table 28).

TABLE 28.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	3	-7.70	-11.0 - -5.0	3.06	4.35*
Before fix.rem.	3	-0.83	- 1.5 - ±0.0	0.76	1.89
1 year	3	+0.17	± 0.0 - +1.0	0.76	0.38
<i>s-y vert</i>					
Imm. post op.	3	-3.67	-5.5 - -1.0	2.36	2.69
Before fix.rem.	3	±0.00	-0.5 - +0.5	0.50	0.00
1 year	3	+0.17	-1.5 - +2.0	1.76	0.16

*Idiopathic anterior crossbite with
bimaxillary mobilization*

Males

Horizontal changes Due to surgery, reference point X had moved an average of 1.8 mm anteriorly.

Insignificant changes were noted at the end of the immobilization term and at the 1 year follow-up (Table 29).

TABLE 29.
Horizontal changes of point X

<i>s-x hor</i>	n	d	Range	s	t
Imm. post op.	4	+1.75	-0.5 - +4.0	1.94	1.81
Before fix.rem.	4	+0.37	-0.5 - +1.5	0.85	0.88
1 year	4	+0.50	-0.5 - +1.5	1.08	0.93

Vertical changes As a result of the surgical procedure, the position of X had changed 2.0 mm, on the average, in the inferior direction and point Y 2.3 mm in the superior direction ($P < 0.001$). Insignificant mean changes in the positions of X

and Y, not exceeding 0.7 mm and 0.4 mm, occurred in the superior direction during immobilization. At the 1 year examination, no significant changes were noted (Table 30).

TABLE 30.
Vertical changes of points X and Y

<i>s-x vert</i>	n	d	Range	s	t
Imm. post op.	4	+2.00	+1.0 - +4.0	1.41	2.83
Before fix.rem.	4	-0.63	-2.0 - +0.5	1.11	1.13
1 year	4	+0.38	-0.5 - +1.0	0.75	1.00
<i>s-y vert</i>					
Imm. post op	4	-2.25	-2.5 - -2.0	0.29	15.59***
Before fix.rem.	4	-0.38	-2.0 - +0.5	1.11	0.68
1 year	4	+0.25	-0.5 - +1.0	0.65	0.77

Females

Horizontal changes Following operation, point X had moved 1.4 mm anteriorly. During the time of intermaxillary fixation and at the 1 year follow-up, no significant changes were observed (Table 31).

TABLE 31.
Horizontal changes of point X

<i>s-x hor</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	4	+1.38	-1.0 - +3.0	1.80	1.53
Before fix.rem.	4	-0.13	-1.0 - -1.5	1.11	0.23
1 year	4	-0.25	-0.5 - ±0.0	0.29	1.73

Vertical changes Table 32 demonstrates a post-operative mean change in the position of X, 1.5 mm inferiorly and a similar change in the position of Y, of 1.1 mm. After immobilization period and at the 1 year follow-up no significant changes could be demonstrated.

TABLE 32.
Vertical changes of points X and Y

<i>s-x vert</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	4	+1.50	-0.5 - +5.5	2.74	1.10
Before fix.rem.	4	±0.00	±0.0 - ±0.0	0.00	0.00
1 year	4	-0.38	-1.0 - ±0.0	0.48	1.57

<i>s-y vert</i>	<i>n</i>	<i>d</i>	Range	<i>s</i>	<i>t</i>
Imm. post op.	4	+1.13	-0.5 - +5.0	2.59	0.87
Before fix.rem.	4	-0.50	-1.0 - ±0.0	0.58	1.73
1 year	4	+0.13	-1.0 - +1.0	0.85	0.29

POSITION OF MAXILLA IN RELATION
TO BONE GRAFTS AND
TRANSOSSEOUS WIRING

Patients with idiopathic and post-traumatic anterior crossbite demonstrated changes in maxillary position during the fixation period.

In order to investigate these findings in detail the patients were divided into three subgroups, *i.e.* without bone grafts (*n* = 43), with bone grafts (*n* = 16) and with bone grafts and mandibular splitting (*n* = 8).

The two first subgroups were compared with reference to the mean changes of point X during the fixation period and the findings are presented in table 33. It is evident from the table that there

were no significant differences between these groups. However, negative and significant correlations were found between horizontal and vertical changes of point X within the groups (Fig. 17 and 18).

TABLE 33.
Horizontal and vertical mean changes (*d*) in patients without and with bone grafts

	without bone		with bone		
	(n = 43)		(n = 16)		
	<i>d</i>	<i>s</i>	<i>d</i>	<i>s</i>	<i>t</i>
<i>s-x hor</i>	0.29	1.50	0.34	1.34	1.47
<i>s-x vert</i>	-2.05	2.49	-1.84	1.73	0.30

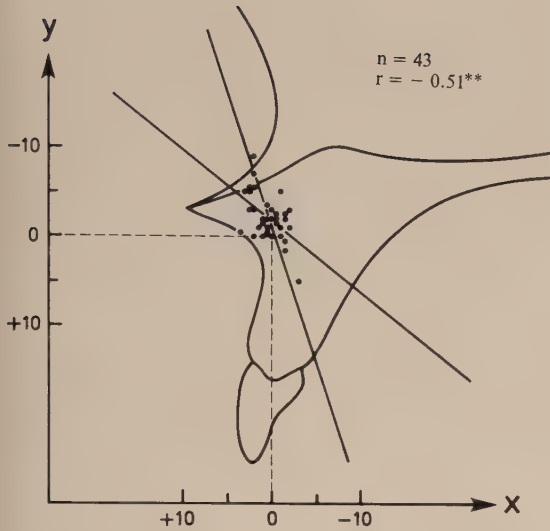


FIG. 17.

Correlation between horizontal and vertical changes of point X in patients without bone grafts.

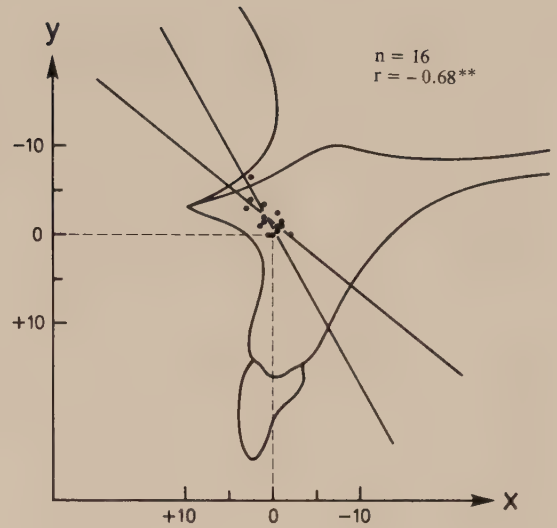


FIG. 18.

Correlation between horizontal and vertical changes of point X in patients with bone grafts and osteosutures.

TABLE 34.

Horizontal and vertical mean changes (d) in patients with bone grafts but without and with mandibular splitting

	without mandibular splitting (n = 16)		with mandibular splitting (n = 8)		
	d	s	d	s	t
s-x hor	0.34	1.34	0.13	0.79	0.91
s-x vert	-1.84	1.73	-0.31	0.80	2.35*

When comparing the two last subgroups no significant differences were observed concerning the positional changes of point X during fixation time (Table 34). However, in the last subgroup five patients demonstrated no vertical changes and three exhibited +0.5, -1.0 and -2.0 mm, respectively.

In contrast to the first and second subgroups no significant association between horizontal and vertical changes of point X was noted in the third subgroup.

CONCLUSION

The male and female patients with *cleft lip and palate* demonstrated no horizontal mean changes in the position of the maxilla during the fixation period. A significant superior change in the position of the posterior part of the maxilla of 1.0 mm ($P < 0.01$) was observed during the fixation period in males. The females demonstrated a greater tendency to superior change of the maxillary position in the range of measurements but no significant mean changes. Both in male and female patients the maxilla was found to have assumed a posterior position of 1.0 mm ($P < 0.01$) at the 1 year follow-up. Thereafter, no further differences in maxillary position could be found.

The patients with *idiopathic and post-traumatic anterior crossbite* demonstrated no horizontal mean changes in the position of the upper jaw during fixation, but in the vertical direction a positional change in the superior direction of the maxilla was found in both males and females. The horizontal and vertical changes during the fixation period have been subjected to a separate investigation. At the 1 and 3 year follow-ups no further horizontal or vertical displacements of the maxilla were observed in either sex.

The patients with *idiopathic short and long face* demonstrated no significant changes in the position of the maxilla postoperatively up to 3 years.

In patients with *idiopathic anterior crossbite with bimaxillary mobilization*, the average change in anterior direction of the maxilla was small both in males and females immediately after operation in comparison with that in the idiopathic and post-traumatic anterior crossbite group. This was due to the backward shift of the mandible in the same operation. The difference in the position of the posterior part of the maxilla in males immediately after operation in contradistinction to the females was due to the necessity of elevating the molar parts of the upper jaw. During the fixation period and at the 1 year follow-up no significant changes were noted.

Comparison of patients without and with bone grafts and osteosutures to those with bone grafts and bimaxillary operation concerning changes in position of the anterior maxilla during immobilization did not demonstrate significant differences. Horizontal changes of the maxilla measured on dental casts and profile radiographs demonstrated very close conformity in patients with cleft lip and palate and those with idiopathic and post-traumatic anterior crossbite. In patients with idiopathic anterior crossbite where the mandible was mobilized and repositioned at the same sitting, no comparison could be made.

FACIAL PROFILE BEFORE AND AFTER SURGERY

Morphological analysis of changes in the facial profile of patients with surgically corrected mandibular protrusion have been reported by, *inter alia*, *Fromm & Lundberg* (1970) and *Björk et al.* (1971).

So far, no accurate investigations have been published of changes in skeletal and soft tissue profiles after Le Fort I osteotomy.

Skeletal and soft tissue profiles were additionally studied on standardized profile radiographs before and after operation in order to further evaluate the effect of surgery. Preoperative morphological measurements of the position of the maxilla in

relation to the anterior cranial base were made and evaluated together with the clinical findings to more precisely classify the deformity.

Characteristics of the patients' profiles were compared with those of a reference group of Swedish students (see below). The preoperative skeletal and soft tissue morphology of the male patients with cleft lip and palate was also compared with a reference group of Danish men with cleft lip and palate (see below).

The soft tissue profile is of particular importance in regard to the patients' own impression of the result.

Reference groups

Results of the profile radiographic analysis have been compared with those of a study by *Sarnäs* (1973) on 145 male and 172 female students at the University of Lund, aged 19 to 23 years. Results of the examination of male patients with cleft lip and palate were also compared with data given by *Dahl* (1970) in an investigation of 153 adult males with operated cleft lip and palate.

MATERIAL

The patients included in the preoperative morphological studies comprise the entire clinical material with the exception of the following 11 patients: the post-traumatic group of 5 males and 1 female because of the history of maxillary fracture, one male with cleft lip and palate and two males and two females from the idiopathic group because of previous surgery on the mandible or incomplete records.

In the postoperative studies, further elimination of patients was necessary because operations on the lower jaw at the same sitting or nasal corrections in the postoperative period were also performed.

The number of measurements in some tables vary in both the pre- and postoperative investigations owing to the presence of partial or full dentures.

METHODS OF ANALYSIS

In the analysis of profile radiographs, the dimensions described by *Lindegård* (1953), *Sarnäs* (1959), *Björk* (1960) and *Solow* (1966) were used. Reference points and lines are situated in the mid-sagittal plane (MSP) or projections in this plane. In cases with double contours, a midcontour was constructed and used. Radiographs of the mandible with mouth open were used for identifying the head of the condyle and buccal cusps of the upper first molars. Measurements were made to the nearest 1/2 mm (0.5) and 1/2 grade (0.5) on two separate occasions in each patient without correction for linear enlargement.

Reference points

Unless otherwise stated, the definitions used are those as given by *Björk* (1960, 1963).

- ba Basion. The most posterior-inferior point of the clivus.
- cd Condylion. The most superior-posterior point of the condylar head.
- s Sella. The centre of the sella turcica arbitrarily determined.
- n Nasion. The most anterior point of the frontonasal suture.
- sp Spinal point. The apex of the anterior nasal spine.
- sp' The transferral of *sp* to a line through *n* and *gn* (*Lindegård*, 1953).
- pm Pterygomaxillare. The intersection between the nasal floor and the posterior contour of the maxilla.
- ss Subspinale. The most posterior point on the contour of the upper alveolar process.
- is Incision superius. The midpoint of the incisal edge of the most prominent upper central incisor.
- is' The transferral of *is* to a line through *n* and *gn* (*Lindegård*, 1953).
- ii Incision inferius. The midpoint of the incisal edge of the most prominent lower central incisor.
- io The projection of *ii* on the occlusal line.
- sm Supramentale. The most posterior point on the contour of the lower alveolar process.
- p gn Prognathion. The point on the mandibular symphysis farthest from *cd*.

- gn Gnathion. The most inferior point on the mandibular symphysis.
- lc Lip contact. The anterior point of intersection between the upper and lower lips (*Sarnäs*, 1959).

Reference lines

- NSL Nasion — sella line. The line through *n* and *s*.
- NSP Nasion — sella perpendicular. A perpendicular to NSL passing through *s*.
The two lines NSL and NSP form a coordinate system to which the upper face morphology has been related. (*Lindegård*, 1953).
- NL Nasal line. The line through *sp* and *pm*¹⁾.
- OL_s Upper occlusal line. The line through *is* and the distobuccal cusp of the first upper molar (M₁). If this tooth was missing, the mesio-buccal cusp of the second upper molar (M₂) was used.
- ML Mandibular line. The tangent to the lower border of the mandible through *gn*.
- RL Ramus line. The tangent to the posterior border of the mandible.
- MBL Mandibular base line. Corresponds to the hypotenuse in which the mandible is circumscribed (*Sarnäs*, 1959).
- NFL Nose — frontal line. The tangent to the nose and forehead (*Sarnäs*, 1973).
- NCL Nose — chin line. The tangent to the nose and the chin (*Sarnäs*, 1973). The two lines NFL and NSL relate to facial soft tissue.

¹⁾ Owing to surgery, this line and related measurements are omitted at the follow-up at 1 and 3 years.

TABLE 35.

<i>Skeletal</i>	Measurements <i>linear</i>	Measurements <i>angular</i>
Cranial base and skull:	n — s	n — s — ba°
Upper face:	s — pm hor s — pm vert ss — pm n — sp' s — is vert	NSL/NL° s — n — ss° NL/+1°

Lower face: $sp' - gn$ NL/ML°
 $sp' - is'$ NL/OL°
 overjet: $is - io$ ML/-1°
 overbite: $ii - io$ beta angle
 mandibular gonial angle
 base length: $pgn - cd$ $s - n - sm$ °

Total face: $n - gn$ NSL/ML°

Soft tissue

Upper face: $s - lc$ vert

Lower face: thickness of upper red lip
 depth of upper lip curvature
 thickness of lower red lip
 depth of lower lip curvature
 lower lip height

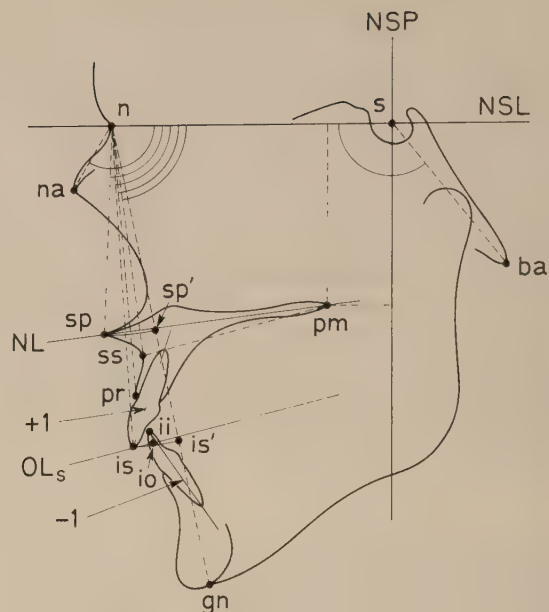


FIG. 20. Reference lines.

Total face: NFL/NCL°
 NSL/NFL°

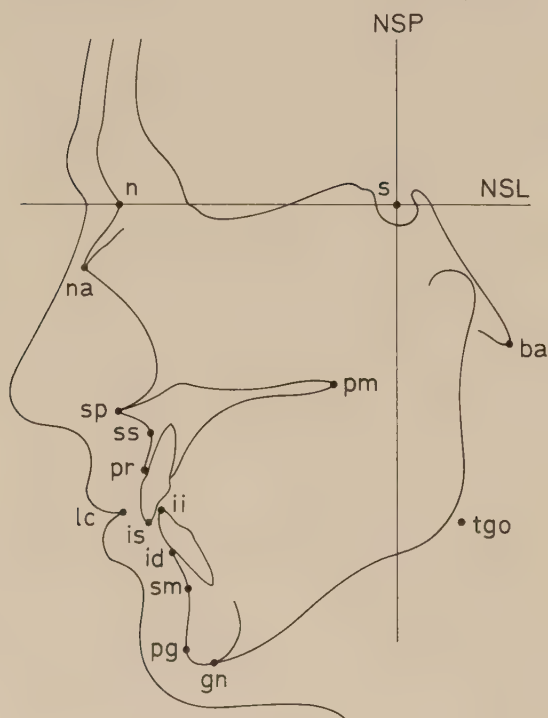


FIG. 19. Reference points.

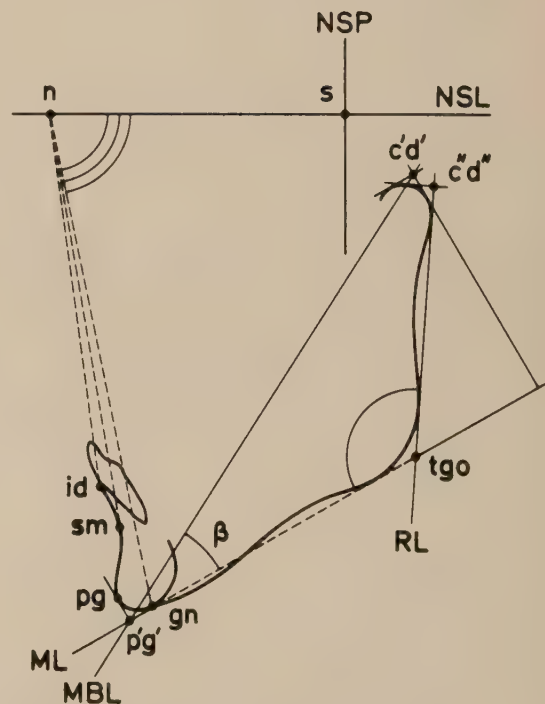


FIG. 21.

Reference points and lines related to the mandible.

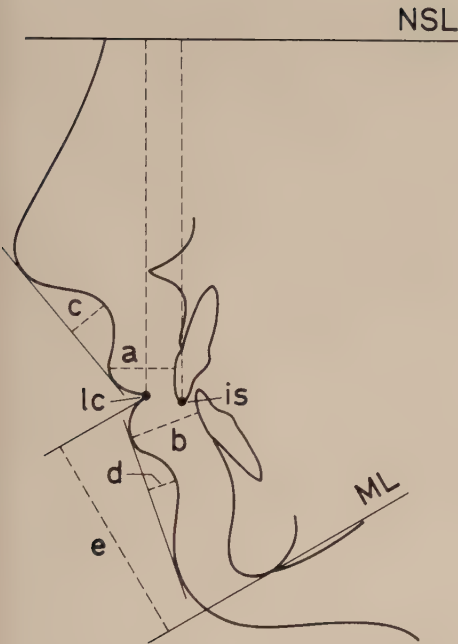


FIG. 22.
Construction of the soft tissue measurements:
a = Thickness of upper red lip
b = Thickness of lower red lip
c = Depth of upper lip curvature
d = Depth of lower lip curvature
e = Lower lip height
f = s – lc vert
g = s – is vert

ERROR OF THE METHODS

Measurements on the radiographs

The error of the method, *i.e.* the precision or variation in repeated observations (*Hallert, 1967*) has been assessed in the following way. Twenty patients, randomly chosen, were each examined

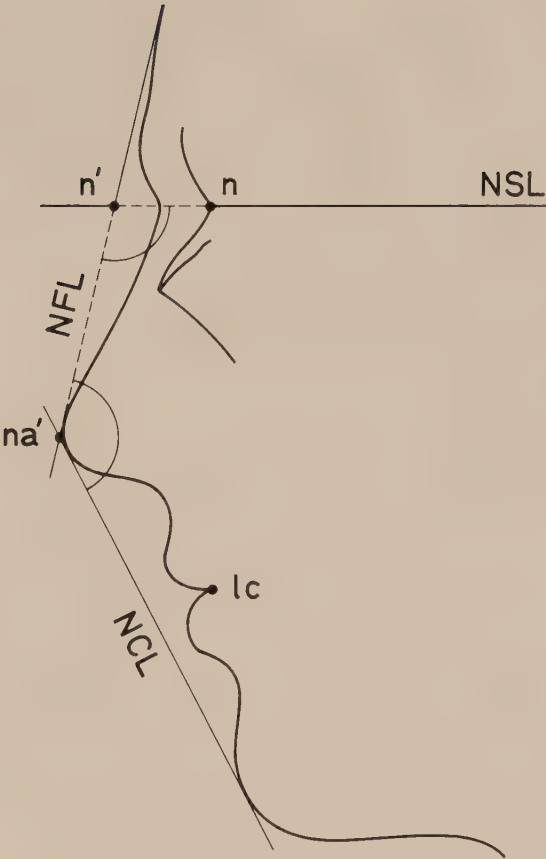


FIG. 23.
The construction of the soft tissue lines NFL and NCL.

radiographically on two different occasions under conditions identical to that used in the entire group, the only difference being the placement of the patient in the cephalostat. The results of the difference in measurements are presented in table 36.

TABLE 36.

Precision, $S_{(i)}$, for double determinations of skeletal and soft tissue dimensions on radiographs obtained at two different examinations of 20 patients.

Skeletal	Measurements linear	$S_{(i)}$	Measurements angular	$S_{(i)}$
Cranial base and skull:	n – s	.38	n – s – ba°	.47
Upper face:	s – pm hor	.33	NSL/NL°	.45
	s – pm vert	.30	s – n – ss°	.43
	ss – pm	.70	NL/+1°	.91
	n – sp'	.25		
	s – is vert	.45		

Lower face:	sp' - gn	.26	NL/ML°	.52
	sp' - is'	.35	NL/OL°	.51
	overjet: is - io	.24	ML/-1°	.53
	overbite: ii - io	.37	beta angle	.35
	mandibular base		gonial angle	.43
	length: pgn - cd	.61	s - n - sm°	.39
Total face:	n - gn	.34	NSL/ML°	.56
<i>Soft tissue</i>				
Upper face:	s - lc vert	.29		
Lower face:	thickness of upper red lip	.34		
	depth of upper lip curvature	.21		
	thickness of lower red lip	.25		
	depth of lower lip curvature	.29		
	lower lip height	.35		
			NFL/NCL°	.49
			NSL/NFL°	.42
Total face:				

PREOPERATIVE MORPHOLOGY

Cleft lip and palate

Males

Analysis was completed on 16 males and results compared both with Dahl's cleft group and Sarnäs' reference group (Table 37).

Skeletal measurements

Upper face The anterior cranial base (n-s), was significantly longer than in Dahl's group ($P < 0.01$). Maxillary retrusion, measured as the angle $s-n-ss^\circ$ was 11.7° smaller ($P < 0.001$) in comparison with Sarnäs' group. The posterior position (s-pm hor) of the maxilla agreed with that in Dahl's study, but was significantly more retruded than in Sarnäs' group ($P < 0.001$). Vertical height (s-pm vert) was greater than in Dahl's group ($P < 0.01$) but did not differ significantly

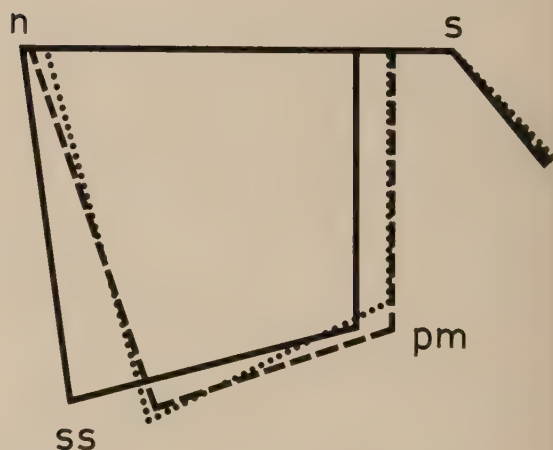


FIG. 24.

Cleft lip and palate, males. The maxilla in relation to the anterior cranial base.

- Reference group (Sarnäs 1973)
- ... Cleft lip and palate group (Dahl 1970)
- - - The present group

from that of Sarnäs. The anterior height of the maxilla ($n-sp'$), however, agreed with both Dahl's and Sarnäs' reference groups (Fig. 24).

Lower face The average mandible in this patient sample was 6.0 mm longer than in Dahl's group ($P < 0.001$). The gonion was 7.5° larger ($P < 0.001$) than in Sarnäs' group, but did not differ from that in Dahl's cleft group. The lower incisors were inclined markedly lingually ($ML/-1^\circ$), 78.0° compared with 94.6° in Sarnäs' group ($P < 0.001$).

Total face Face height ($n-gn$) was 6.4 mm greater than in Sarnäs' reference group ($P < 0.001$), but did not differ significantly from that of Dahl's group. Similar relationships were found when comparing the NSL/ML angle.

Soft tissue measurements

Soft tissue contours differed significantly from those of Sarnäs' reference group; the curvature of the lower lip was flatter ($P < 0.01$) and the lower lip height greater ($P < 0.01$). The facial angle (NSL/NFL $^\circ$) was 8° less than in the Sarnäs group ($P < 0.001$).

Females

Analysis was carried out on 8 females and results compared with Sarnäs' group (Table 38).

Skeletal measurements

Upper face The upper cranial base length ($n-s$) did not differ from that of the Sarnäs reference group. A considerable maxillary retrusion ($s-n-ss^\circ$) was seen, 73.9° , compared with 81.0° in Sarnäs' group ($P < 0.001$). The length of the maxilla ($ss-pm$) and its anterior ($n-sp'$) and posterior heights ($s-pm$ vert) did not differ significantly from the corresponding values in the Sarnäs group. The posterior portion of the maxilla ($s-pm$ hor) was situated significantly posteriorly ($P < 0.01$) (Fig. 25).

Lower face No significant difference could be demonstrated in mandibular protrusion between the female cleft group and Sarnäs' group. The gonion angle was 7.0° larger than in the Sarnäs group ($P < 0.01$). The overjet was -4.6 mm, compared with $+4.1$ mm in Sarnäs' group, a total

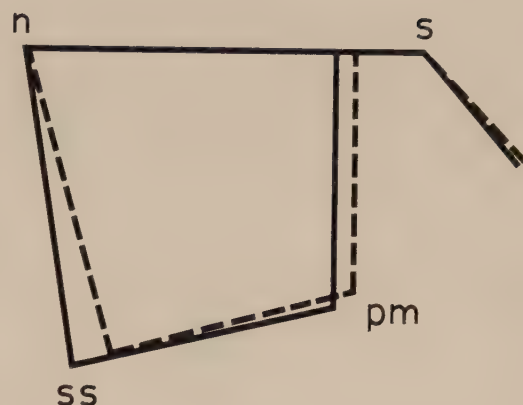


FIG. 25.

Cleft lip and palate, females. The maxilla in relation to the anterior cranial base.

— Reference group (Sarnäs 1973)
 - - - The present group

difference of 8.7 mm ($P < 0.01$). The inclination of the lower incisors ($ML/-1^\circ$) was 78.8° , compared with 94.3° ($P < 0.001$) in the Sarnäs group.

Total face Face height ($n-gn$) and the angle NSL/ML did not differ significantly from those of the reference group.

Soft tissue measurements

The depth of lower lip curvature was greater ($P < 0.01$) and the height of lower lip higher ($P < 0.01$) than in Sarnäs' group. The facial angle (NFL/NCL) was significantly smaller ($P < 0.001$).

Idiopathic anterior crossbite

Males

This group consisted of 38 males and was compared with Sarnäs' group. Results are given in table 39.

Skeletal measurements

Upper face It is evident from the table that differences were found mainly in the antero-posterior direction. The apical base ($ss-pm$) was 5.6 mm shorter than in Sarnäs' group ($P < 0.001$). The entire maxilla was in a posterior position relative to the anterior cranial base ($s-pm$ hor) ($P < 0.001$).

Despite the shorter anterior cranial base ($n-s$), the angle $s-n-ss$ was only 75.7° , compared with 82.2° in Sarnäs' group ($P < 0.001$). The posterior height of the maxilla ($s-pm$ vert), like the anterior ($n-sp'$), did not differ significantly from that of Sarnäs' group (Fig. 26).

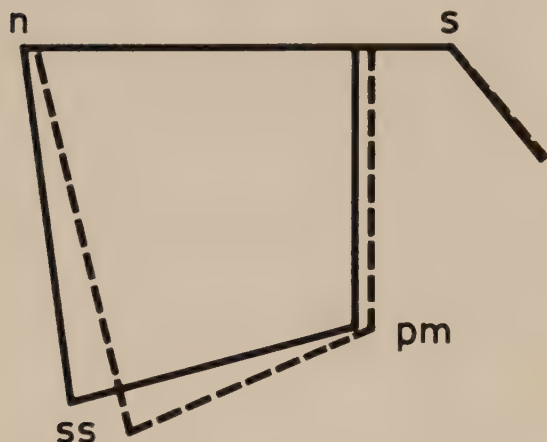


FIG. 26.

Idiopathic anterior crossbite, males. The maxilla in relation to the anterior cranial base.

— Reference group (Sarnäs 1973)
 - - - The present group

Lower face The lower anterior face ($sp'-gn$) was 7.3 mm larger ($P < 0.001$) and the mandibular base 9.7 mm longer ($P < 0.001$) than in Sarnäs' group. The inclination of the lower incisors, measured as $ML/-1^\circ$, was less pronounced and 18.3° smaller than in the control group ($P < 0.001$). A considerable discrepancy was found between the edges of the upper and lower incisors, with a negative value of 5.3 mm for the horizontal overbite (overjet), compared with a positive value of 4.2 mm in Sarnäs' group. Hence, there was an overall difference of 9.5 mm, which was significant ($P < 0.001$). There was also a certain tendency to mandibular protrusion ($s-n-sm$), 82.3° compared with 79.9° in Sarnäs' group.

Total face Face height ($n-gn$) was 8.8 mm greater than in the control group ($P < 0.001$). This was related to a larger gonion angle, 136.2° ($P < 0.001$) and a longer mandibular base ($P < 0.001$). The

posterior position of the maxilla ($s-pm$ hor) contributed further to this increase in face height ($P < 0.001$). The mandibular line ML was markedly declined, and the angle NSL/ML was 7.3° larger than in Sarnäs' group ($P < 0.001$).

Soft tissue measurements

As for the soft tissue profile, significant differences were found for all comparable measurements. The upper red lip was 2.5 mm thicker than in Sarnäs' group ($P < 0.01$) and the curvature of the lip was more marked ($P < 0.01$). The lower lip curvature was less pronounced ($P < 0.001$) and lower lip height was 3 mm greater ($P < 0.001$). The facial angles NSL/NFL and NFL/NCL showed significant differences ($P < 0.001$), *i.e.* abnormally flat face.

Females

Twenty-five females were examined and the results were compared with those in Sarnäs' group (Table 40).

Skeletal measurements

Upper face The posterior maxilla ($s-pm$ hor) was situated 4.2 mm closer to the sella turcica than in Sarnäs' study group ($P < 0.001$). The angle $s-n-ss$ was only 76.6° , compared with 81.0° in the Sarnäs group ($P < 0.001$).

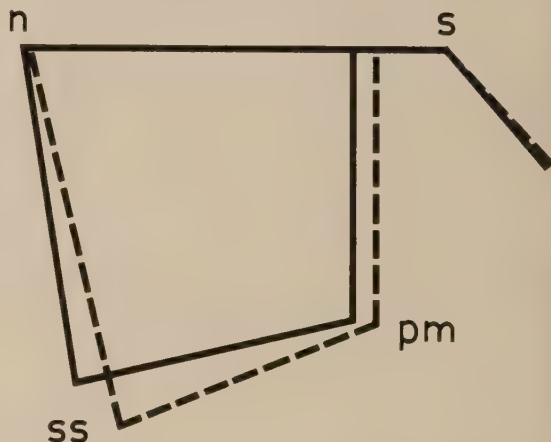


FIG. 27.

Idiopathic anterior crossbite, females. The maxilla in relation to the anterior cranial base.

— Reference group (Sarnäs 1973)
 - - - The present group

Lower face The females also demonstrated a certain amount of mandibular protrusion ($s-n-sm^\circ$), which exceeded that of Sarnäs' group by 3.7° ($P < 0.01$), and the mandibular base length was 8.2 mm longer ($P < 0.001$). The anterior crossbite (overjet) was less marked in this group, -2.3 mm compared with $+4.1$ mm, a total difference of 6.4 mm ($P < 0.001$). The lower incisors were notably inclined lingually, 79.6° in comparison with 94.3° ($P < 0.001$).

Total face Total face height ($n-gn$) was, on the average, 5.8 mm greater than in the reference group ($P < 0.01$), with an increased angle (NSL/ML) ($P < 0.01$).

Soft tissue measurements

The upper lip was significantly thicker ($P < 0.001$) than in Sarnäs' study. Lower lip curvature was significantly decreased ($P < 0.001$), but its thickness was practically the same in both groups. The height of the lower lip was greater ($P < 0.01$) and the facial angle NFL/NCL was 8.1° larger ($P < 0.001$).

Idiopathic short face

Females

This study was carried out on 5 females and the results were again compared with Sarnäs' group (Table 41).

Skeletal measurements

Upper face The posterior position ($s-pm$ hor), the vertical height ($s-pm$ vert) and the length ($ss-pm$) of the maxilla agreed with those in Sarnäs' study, but the height of the alveolar process ($sp'-is'$) was 8 mm less ($P < 0.001$). The ratio between the edges of the upper incisors and the upper lip, expressed as the difference between $s-lc$ vert and $s-is$ vert, was 0.7 mm, signifying that the upper lip concealed the incisors completely.

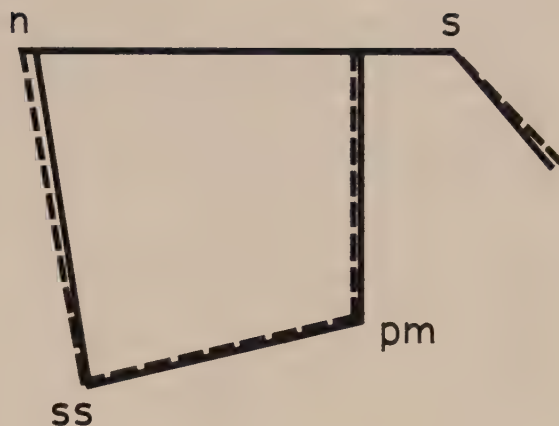


FIG. 28.

Idiopathic short face, females. The maxilla in relation to the anterior cranial base.

— Reference group (Sarnäs 1973)
 - - - The present group

Lower face The gonion angle was smaller, 114.2° , compared with 125.7° in Sarnäs' group ($P < 0.001$). The angle MBL/ML was significantly larger ($P < 0.01$). Anterior lower face height ($sp'-gn$) was markedly reduced and showed a difference of 11.8 mm ($P < 0.001$), due mainly to the shortness of the alveolar process of the upper jaw (see above).

Total face The face height ($n-gn$) was 12.7 mm less ($P < 0.001$) and the angle NSL/ML was only half as large as that in Sarnäs' group, *i.e.* 16.2° ($P < 0.001$).

Soft tissue measurements

The soft tissue profile differed significantly from that of Sarnäs' group. The lower red lip was thicker ($P < 0.001$), the lower lip height shorter ($P < 0.001$), and the facial angle (NFL/NCL) more obtuse ($P < 0.01$).

Idiopathic long face

Females

As this group consisted of only 3 patients, statistics were limited to the upper face. However, the characteristic feature of this facial deformity was an overdevelopment of the alveolar process of the

upper jaw ($sp' - is'$) and disproportion between the edges of the upper incisors and the upper red lip, expressed as the difference between $s - lc$ vert and $s - is$ vert of 6.2 mm. Total face height ($n - gn$) was measured on only two patients, as the third had a full denture of the lower jaw.

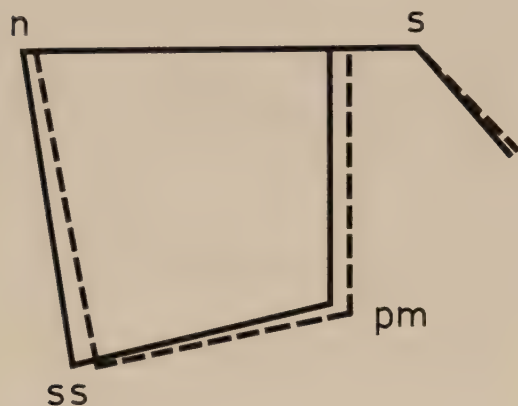


FIG. 29.

Idiopathic long face, females. The maxilla in relation to the anterior cranial base.

—— Reference group (Sarnäs 1973)
 --- The present group

CONCLUSION

Cleft lip and palate, males Similar anatomic relationships to those recorded by Dahl were found also in the present series. One exception was the position of the maxilla relative to the anterior cranial base, where the maxillary retrusion was more pronounced and the posterior height of the maxilla greater than in Dahl's patients. The plausible explanation for this difference is that the present male patients were selected for surgical correction. Compared with Sarnäs' reference group, the patients demonstrated very pronounced maxillary retrusion and a greater total facial height. The gonion angle was larger and the lower incisors markedly inclined lingually.

Cleft lip and palate, females Here, comparison could be made only with Sarnäs' group, and demonstrated a significant retrusion of the maxilla. As in the male patients, the posterior height of the

maxilla was similar to that found in Sarnäs' group. The lower incisors showed lingual tipping, and an anterior crossbite was present.

When comparing the male and female cleft lip and palate patients the total face height ($n - gn$) and the maxillary retrusion measured as the angle $s - n - ss$ were more pronounced in the male group.

Idiopathic anterior crossbite, males and females As there was no difference between males and females in this category, their findings are presented together. Both sexes had a short maxilla in a retruded position relative to the anterior cranial base. The mandible was long with increased gonion angle, resulting in a large total face height. An anterior crossbite was present with lingual inclination of the lower front teeth. Differences in the soft tissue profile were particularly related to a less prominent nose and a long lower lip height, resulting in flat facial profile.

Idiopathic short and long face These two entities of maldeveloped upper jaw with concomitant effects on the facial outline are mainly characterized by over or underdevelopment of the alveolar process of the maxilla.

POSTOPERATIVE MORPHOLOGY

The facial profile 1 and 3 years after surgery was studied in patients with *cleft lip and palate*, *idiopathic anterior crossbite* and *idiopathic short face* (cf. p. 62). The patients with idiopathic long face were excluded because of their small number. The aim of this investigation was to determine the mean changes in skeletal and soft tissue profiles 1 year and 3 years after surgery. The results are demonstrated in tables 37–41.

The mean values of the facial profile measurements 1 year after operation are presented in tables 37–41 together with the measurements of the preoperative radiographs and the reference group.

As no changes were revealed in facial morphology between the 1 and 3 year follow-ups, the facial profile one year after operation represents the surgical result.

Skeletal and soft tissue profiles in the patients with *idiopathic anterior crossbite* are visualized in facial diagrams of males and females before and 1 year after operation (Fig. 30–33).

Owing to the surgical procedure, reference points, lines and angles depending on points *sp* and *pm* could not be reproduced.

Cleft lip and palate, males (Table 37)

The position of the maxilla in relation to the anterior cranial base, judged by the angle $s-n-ss$, showed an increase of 4.6° ($P < 0.001$). A similar change in the overjet was noted of 5.9 mm ($P < 0.001$). Furthermore, the mandibular angle (gonion angle) was more obtuse at the 1 year follow-up, 1.2° ($P < 0.01$).

The only change in the soft tissue profile concerned the contour of the upper lip, which increased in depth 0.7 mm ($P < 0.01$). Between the 1 and 3 year follow-ups, no changes were found in the skeletal or soft tissue profiles.

Cleft lip and palate, females (Table 38)

Here, the only changes were those in the relation of the maxilla to the anterior cranial base, determined by the angle $s-n-ss$. There was an increase of 4.5° in this angle ($P < 0.01$). A positive change in the overjet was also noted, 6.3 mm ($P < 0.01$). The skeletal and soft tissue profiles were unchanged at the 3 year follow-up.

Idiopathic anterior crossbite, males (Table 39)

Several changes in the skeletal and soft tissue profiles were observed at the one year examination. Following the repositioning of the maxilla, increases were found in the $s-n-ss$ angle of 7.0° ($P < 0.001$), in the $s-is\ vert$ of 2.6 mm ($P < 0.01$) and in the overjet of 8.0 mm ($P < 0.001$). As a consequence of the skeletal changes the soft tissue profile was of increased depth of 0.8 mm in the lower lip curvature, an increase of 1.2 mm in the NSL/NFL angle ($P < 0.001$), a decrease of 3.9 mm in thickness of the upper red lip ($P < 0.001$) and a decrease of 2.5° in the NFL/NCL angle ($P < 0.001$).

The 3 year follow-up revealed no further changes in the skeletal or soft tissue profile.

Idiopathic anterior crossbite, females (Table 40)

As with the males patients, a similar pattern of changes was observed in the skeletal framework of females at the 1 year follow-up. The $n-s-ss$ angle and the overjet showed increases of 7.0° ($P < 0.001$) and 6.5 mm ($P < 0.001$), respectively. Decreases were noted in facial height, expressed as the distance $n-gn$, of 3.5 mm ($P < 0.01$) and in the NSL/ML angle of 3.0° ($P < 0.01$). As for the soft tissue profile, there was an increase of 1.0 mm in the depth of lower lip curvature ($P < 0.001$) and of 1.4° in the NSL/NFL angle ($P < 0.001$). The thickness of upper red lip showed a decrease of 2.4 mm ($P < 0.001$).

Skeletal and soft tissue profiles were unchanged at the 3 year examination.

Idiopathic short face

Because of the small number of patients, findings at the 1 and 3 year follow-ups are presented only in table 41.

CONCLUSION

Skeletal and soft tissue profiles in patients with *cleft lip and palate*, *idiopathic anterior crossbite* and *idiopathic short face* have been analyzed following surgery. Significant changes were observed 1 year after operation in patients with *cleft lip and palate* and those with *idiopathic anterior crossbite*. The position of the maxilla, expressed as the angle $s-n-ss$, was improved and the anterior crossbite eliminated. In *cleft lip and palate* patients this angle increased 4.6° in males and 4.5° in females and in patients with *idiopathic anterior crossbite* it increased 7.0° in both males and females. Significant changes in the soft tissue profile were noted in patients with *idiopathic anterior crossbite*, where the thickness of the upper red lip decreased 3.9 mm in males and 2.4 mm in females. Similar but insignificant decrease in thickness of the upper red lip in *cleft lip and palate* patients was also noted.

The patients with *idiopathic short face* showed an improved position of the front teeth in relation to the upper red lip.

At the 3 year follow-up, no further significant skeletal or soft tissue changes were noted.

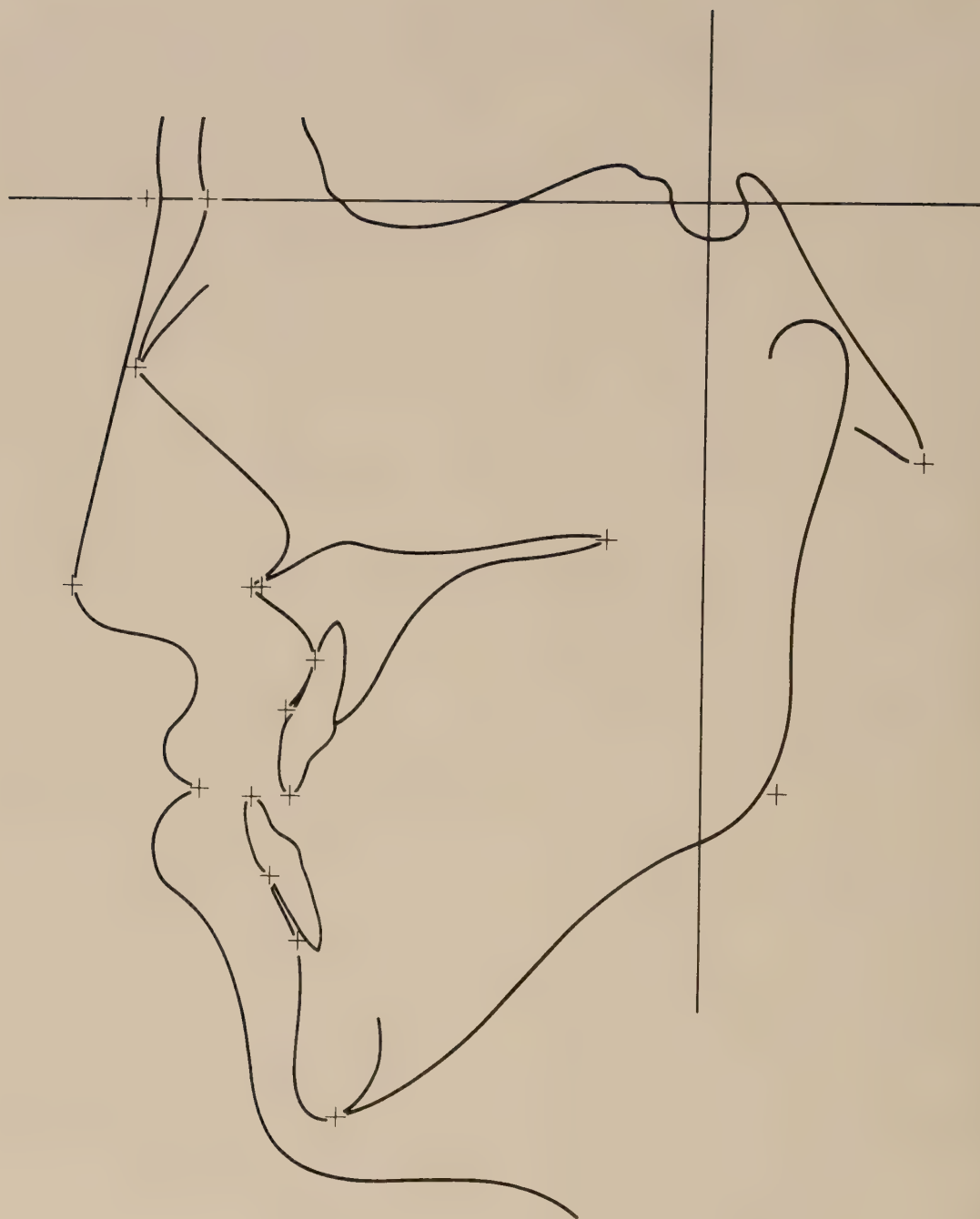


FIG. 30.
Facial diagram constructed from mean measurements of
the male group with *idiopathic anterior crossbite* before
operation.

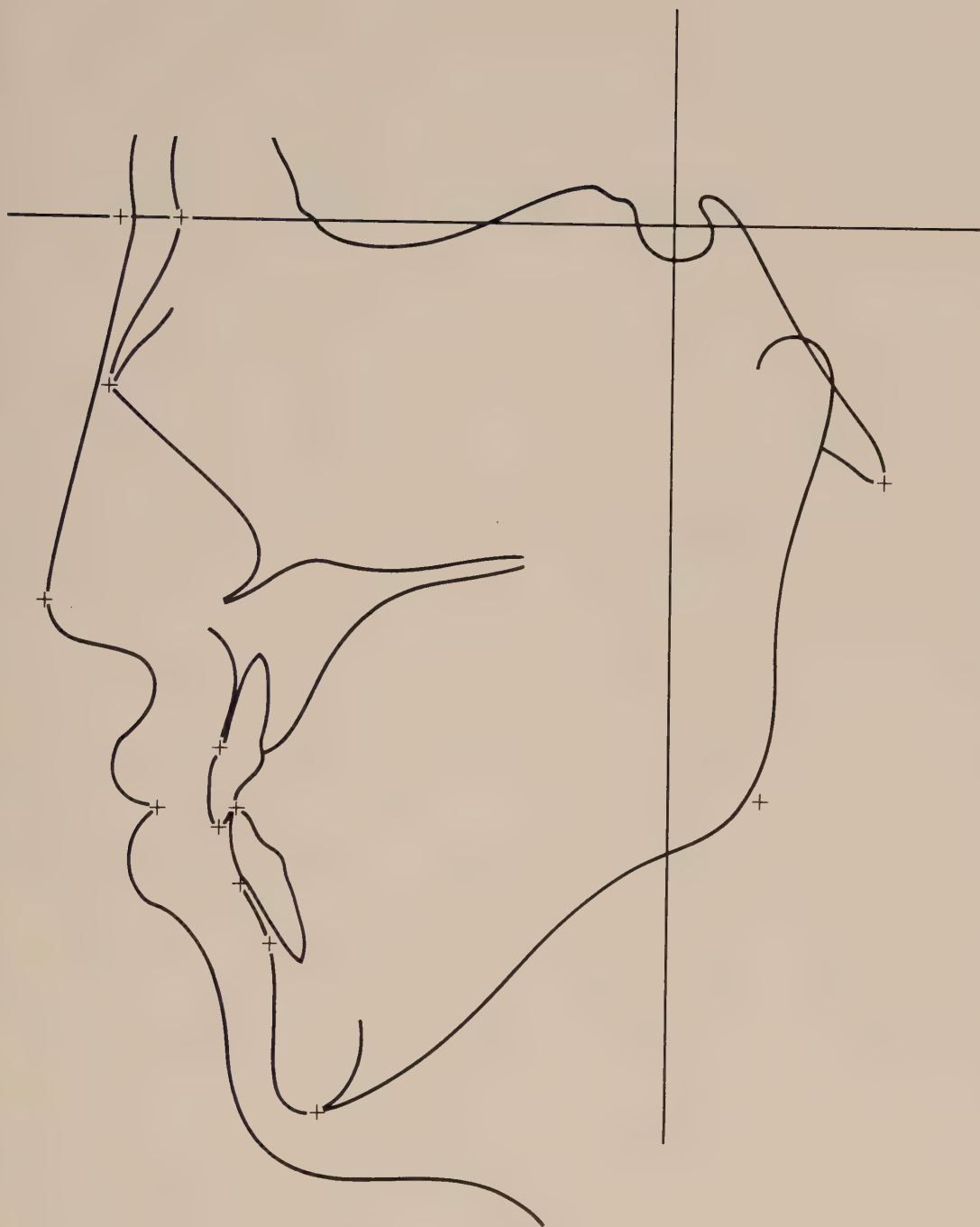


FIG. 31.
Facial diagram constructed from mean measurements of
the male group with *idiopathic anterior crossbite* 1 year
after operation.

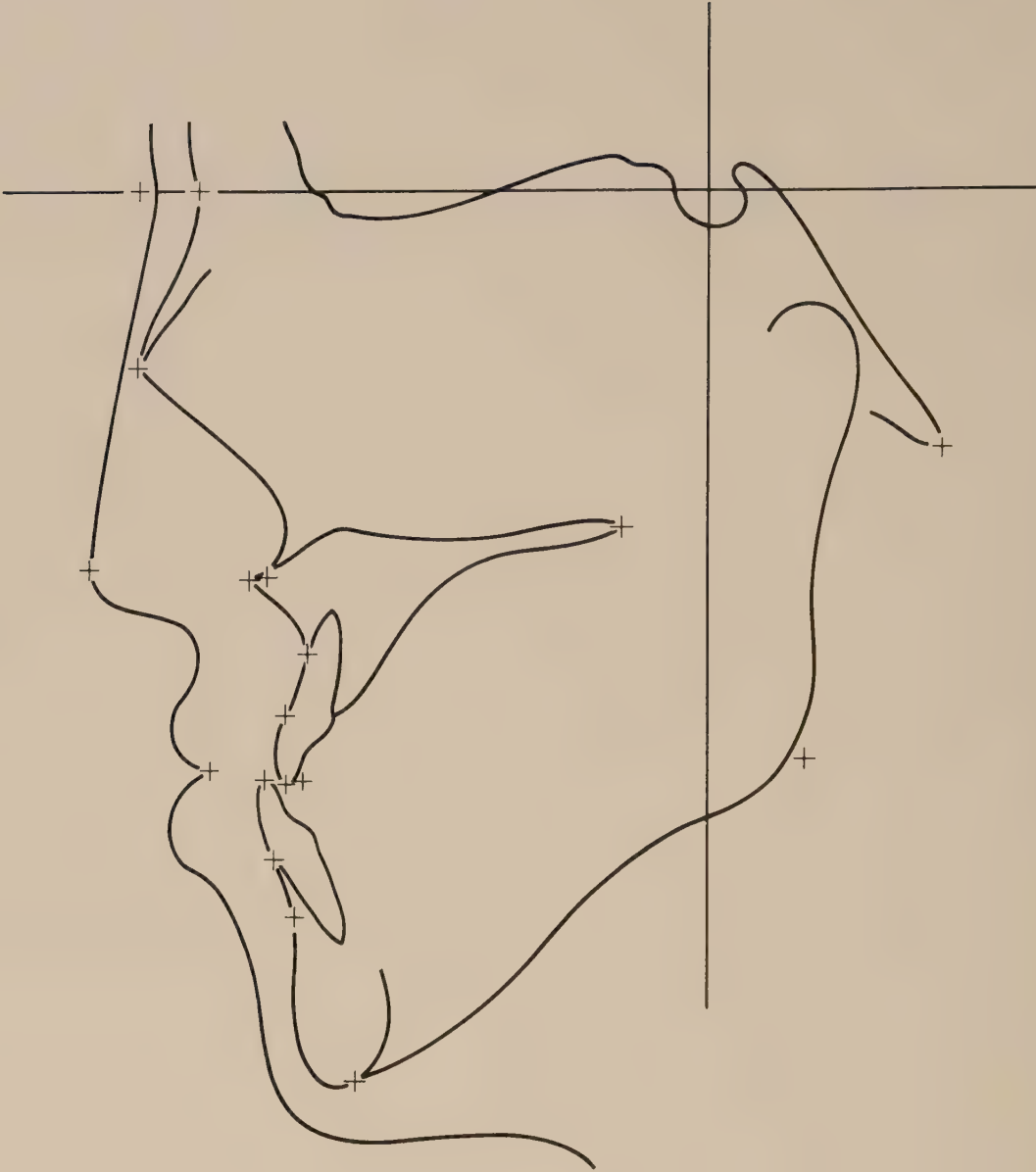


FIG. 32.
Facial diagram constructed from mean measurements of
the female group with *idiopathic anterior crossbite* before
operation.

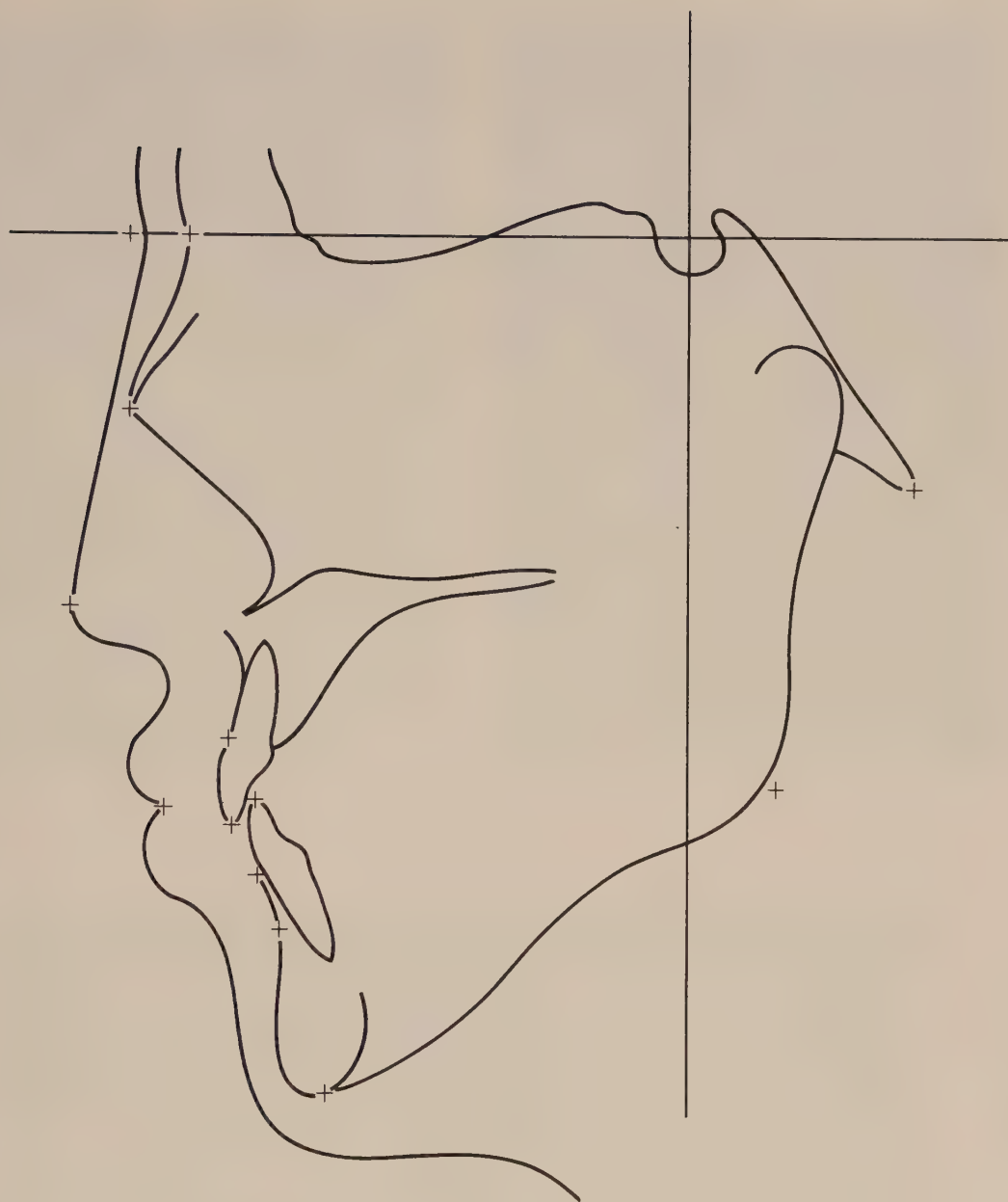
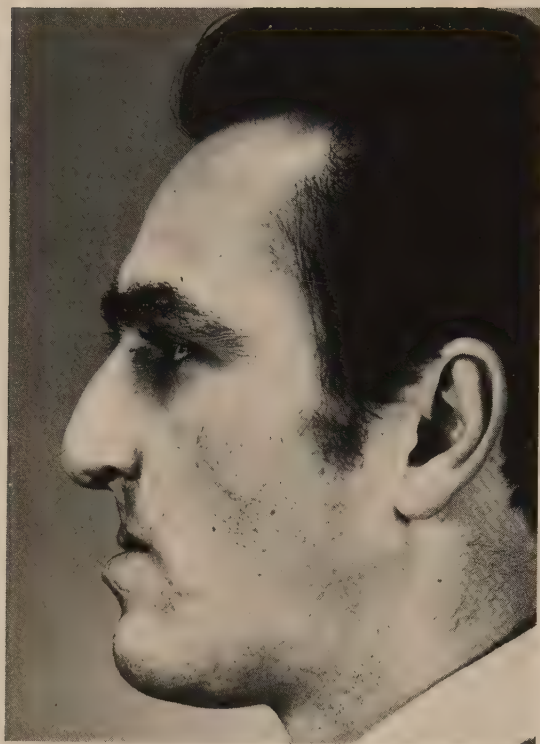
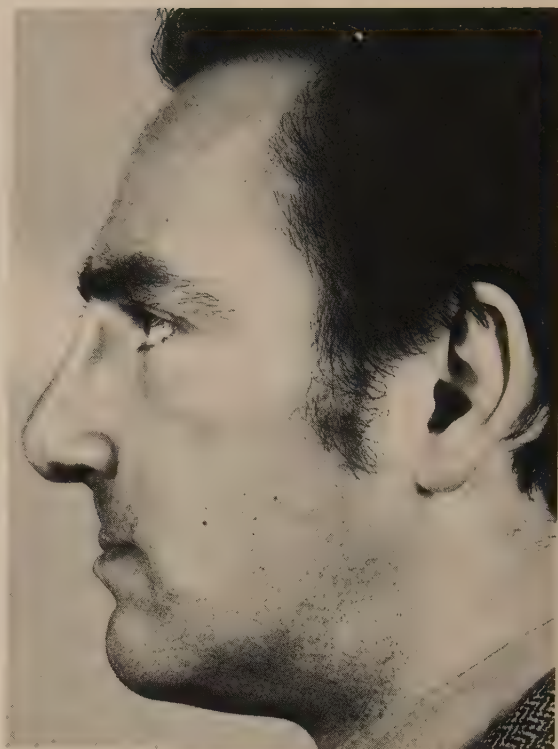


FIG. 33.

Facial diagram constructed from mean measurements of the female group with *idiopathic anterior crossbite* 1 year after operation.



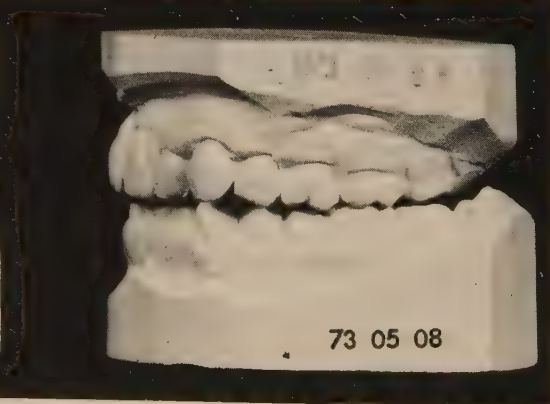
a. Preoperative profile.



c. Profile after maxillary mobilization and bone graft to nose.



b. Preoperative occlusion.



d. Postoperative occlusion.

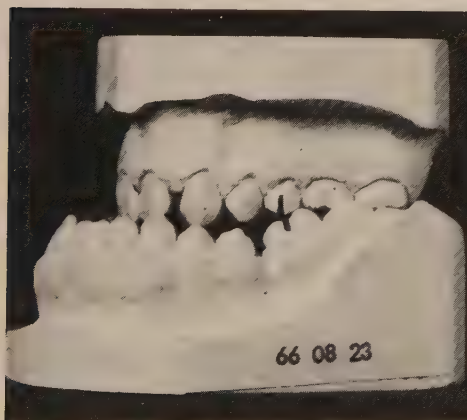
Fig. 34. Patient with cleft lip and palate



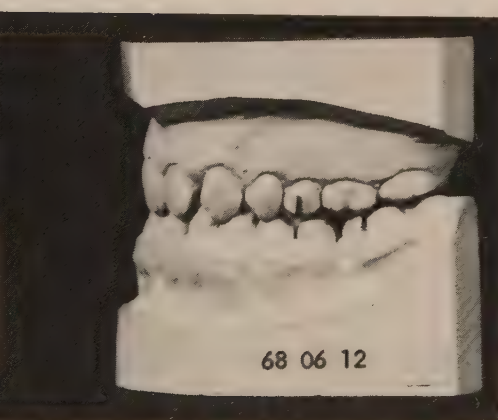
a. Preoperative profile.



c. Profile after maxillary mobilization.



b. Preoperative occlusion.



d. Postoperative occlusion.

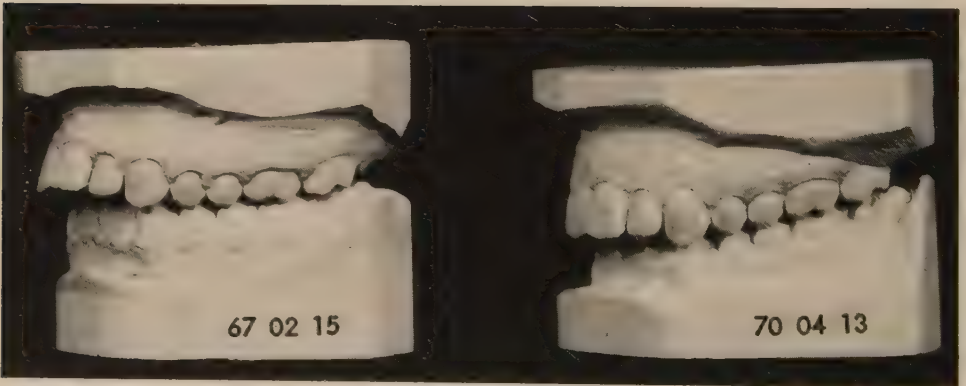
Fig. 35. Patient with idiopathic anterior crossbite



a. Preoperative.



c. Postoperative.



b. Preoperative occlusion.

d. Postoperative occlusion.

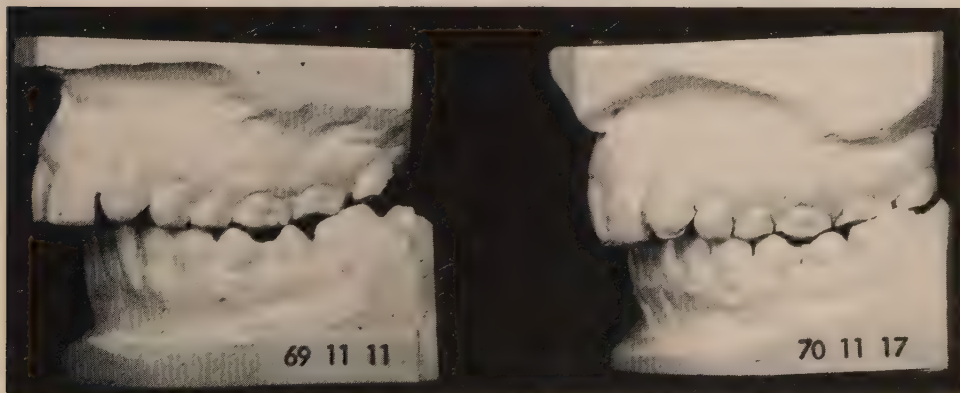
Fig. 36. Patient with idiopathic short face



a. Preoperative.



c. Postoperative.



b. Preoperative occlusion.

d. Postoperative occlusion.

Fig. 37. Patient with idiopathic long face

GENERAL DISCUSSION

The majority of people with dental malocclusion are cared for orthodontically during the growth period, but this treatment is limited to corrections of incongruity of the dental arches and/or malposed single teeth. When the relationship between the bases of the upper and lower jaws is very abnormal, the therapeutic possibilities of orthodontics are limited. This raises the question of indications for surgical correction, possibly combined with pre- or postoperative orthodontics.

The position of the maxilla after operation was studied on profile radiographs with the aid of metallic implants. During the fixation period, no significant changes in horizontal maxillary position were found in any of the patients. In the vertical direction, significant changes were found in both *cleft lip and palate* and *idiopathic and post-traumatic anterior crossbite* groups of patients.

The *cleft lip and palate* group demonstrated significant changes only of point Y in males. An insignificant superior shift ($P < 0.05$) of X and Y was observed in the females and of point X in the males. The number of patients was, however, small.

In the *idiopathic and post-traumatic anterior crossbite* group, the maxilla was found to have moved significantly upwards in both the males and females during the fixation period. The following factors may be considered in the search for an explanation of the changes in maxillary position during the fixation period.

1. The muscles directly or indirectly attached to the upper jaw, *i.e.* the buccinator, the tensor and the levator veli palatini muscles.
2. Intermaxillary fixation.
3. Suspension wires.
4. Dental occlusion.
5. The influence of lower jaw.
6. Bone grafts and osteosutures.

The pull of the buccinator muscles attached to the posterior maxilla and the pterygomandibular raphe may counteract the antepositioning of the upper jaw. The tensor and levator veli palatini muscles attached to the soft palate may have a similar effect. It is possible that the function of these muscles may, in part, explain the backward and upward shift of the maxilla observed in some of the patients during the fixation period.

By means of dental grinding, normal occlusion is secured before operation and is maintained by interdental fixation with steel wires. The upper and lower jaws are firmly interfixed and the position of the upper jaw in relation to the cranial base is thus determined by the length of the mandible and the planned facial height.

Despite these measures and the use of suspension wires and/or bone grafts and osteosutures, significant changes in maxillary position were still observed during the fixation period in patients with *idiopathic and post-traumatic anterior crossbite*. To elucidate this problem further, three subgroups were studied: those without bone grafts, those with bone grafts and those with bone grafts and mandibular splitting. Comparisons of these groups did not reveal any significant differences in maxillary position. Differences may, however, eventually appear when a larger bimaxillary series of patients becomes available for comparative study.

From the end of fixation to the 1 year follow-up, significant changes in maxillary position were observed only in *cleft lip and palate* patients. Here, a backward horizontal move of 1.0 mm was noted. Several untoward factors may be responsible for this retropositioning of the maxilla. Osseous defects and the existence of two or three maxillary segments create an unfavourable situation for healing and stabilization after removal of fixation appliances. Probably the lack of bone grafting

in the majority of these patients was one reason for this relapse and routine use of bone grafting and intraosseous wiring would probably reduce this tendency.

Another factor of probable importance is the previously operated lip, which may exert pressure on the antepositioned maxilla. This assumption is strengthened by the postoperative morphological analysis, which demonstrated a thinner upper lip at the 1 year follow-up, due to stretching, compared with the preoperative findings.

The follow-up study demonstrated that *after 1 year* no changes occur in maxillary position in patients with *cleft lip and palate, idiopathic and post-traumatic anterior crossbite and idiopathic short face, i.e.* the maxilla is stabilized.

Revascularization of maxillary segments or of the entire lower part of the upper jaw after osteotomy has been studied experimentally on monkeys and clinically (Bell, 1969, 1973, Bell & Levy, 1971, Rontal & Hohmann, 1972). These investigations have demonstrated rapid revascularization of bone and teeth. This is believed to be due to the anastomoses existing between gingival, palatal, nasal and periodontal branches of the maxillary artery with plexus formation within the maxilla.

Investigations of reinnervation of maxillary teeth after segmental osteotomy of the anterior portion with repositioning have been done in animal experiments and clinically (Leibold *et al.*, 1971, Ware & Ashamalla, 1971, Pepersack, 1973). The interesting problem of reinnervation of the maxilla by Le Fort I osteotomy with bone grafts filling the gaps in the osteotomy sites has not been the subject of experimental or clinical investigation. However, several clinical observations have demonstrated that maxillary teeth after Le Fort I osteotomy are insensible for a period of months but, as a rule, later recover sensibility with few exceptions. Those teeth may, however, be vital but denervated (Mårtensson, 1950, Poswillo, 1972). In order to investigate the pathways of reinnervation, a clinical study has recently been started on our operated patients.

Concerning the surgical treatment, alternative methods are available, such as osteotomies and/or

osteotomies of the lower jaw and operations on the upper jaw, in particular the Le Fort I osteotomy. Evidence produced in this study has shown that surgical correction of the upper jaw by Le Fort I osteotomy is a valuable method that can yield good results. Observations made on the present material suggested the following indications for Le Fort I osteotomy.

In patients with anterior crossbite in combination with a retruded and/or underdeveloped maxilla (in relation to the anterior cranial base, cf. Sarnäs' reference group) and where the position of the mandible is in conformity with the reference group, a Le Fort I osteotomy is indicated. Divergent maxillary position in relation to the facial midline or to the horizontal plane as the cause of dental malocclusion are also indications for Le Fort I osteotomy, provided that the lower jaw is in proper position relative to the anterior cranial base and the facial midline. These indications for Le Fort I osteotomy are applicable to the *idiopathic and post-traumatic anterior crossbite* group of patients as well as those with *cleft lip and palate*.

In instances where less pronounced maxillary retrusion and/or underdevelopment is combined with mandibular protrusion, where the angle $s-n-sm$ is larger than that of the reference group, the question arises as to which jaw should be operated. Faulty position of one or both jaws in relation to the facial midline or the horizontal plane necessitates osteotomy of the affected jaw, *i.e.* maxillary, mandibular or bimaxillary osteotomy. Where no asymmetry but a minor degree of maxillary retrusion and a moderate anterior crossbite are present, surgical correction of the occlusion can be performed either by maxillary or mandibular osteotomy with equivalent results as regards facial harmony and dental occlusion. Cumulative experience favours maxillary osteotomy because it is technically easier to perform and less apt to be followed by postoperative complications than various types of mandibular surgery, *i.e.* swelling, nerve injuries, tendency to relapse (Hogeman 1951, Trauner 1973).

If the discrepancy between the position of the maxilla and mandible is severe and anterior crossbite pronounced, both jaws should be subject to osteotomy and correction of position.

There is, rarely, extreme divergency in the vertical height of the lower part of the maxilla secondary to overgrowth or underdevelopment of its alveolar process. These two clinical entities, namely *idiopathic long face* and *idiopathic short face*, are presented in this study with a description of their clinical and morphological characteristics. No such presentation could be traced in the literature. The only way to correct the basic anomaly in these patients and to secure the proper relationship between the upper front teeth and the lip line is by

Le Fort I osteotomy with shortening or lengthening of the alveolar process.

The appropriate age for maxillary osteotomy must be estimated individually according to termination of skeletal growth. For psychological reasons osteotomy may, though rarely, be performed before skeletal growth has ceased. An upper age limit for Le Fort I osteotomy cannot be given; the oldest patient in this study was 58 and was operated because of post-traumatic anterior crossbite.

SUMMARY

The purpose of the present investigation of maxillary osteotomy in 106 patients with maxillo-facial deformity was to evaluate the result of Le Fort I osteotomy in respect to skeletal and soft tissue healing, complications, changes in dental occlusion and position of the maxilla, and alterations in the skeletal and soft tissue profiles.

The material represented all patients operated from March 1964 to March 1973 and comprised 62 males and 44 females with mean ages of 27 and 25 years, respectively. The patients were divided according to clinical and morphological characteristics and etiology into 4 groups, *i.e.* cleft lip and palate, idiopathic and post-traumatic anterior crossbite, idiopathic short face and idiopathic long face.

The postoperative changes in dental occlusion and the position of the maxilla were analysed at intervals up to 3 years with the aid of dental casts and standardized profile radiographs. The position of the maxilla, relative to the anterior cranial base, was accurately determined by means of metallic implants in the upper jaw. The results are presented as mean differences.

The dental occlusion remained, for the most part, stable throughout the observation period. In the idiopathic and post-traumatic anterior crossbite group of male patients, a small but not clinically important relapse was observed (0.6 mm) at the 1 year follow-up.

The position of maxilla in the cleft lip and palate patients did not shift during the fixation period, in the anterior part, while the posterior portion moved upwards 1.0 mm in males. A posterior shift of 1.0 mm was observed in both sexes at the 1 year follow-up after which no further changes occurred.

Patients with *idiopathic and post-traumatic anterior crossbite* showed an upward movement of the

maxilla during the period of immobilization. In males, the anterior maxilla moved superiorly 1.8 mm and the posterior portion 0.8 mm. The females exhibited a 2.3 mm elevation of the anterior portion and 1.1 mm of the posterior portion. No further changes were recorded in maxillary position after removal of fixation.

In 8 female patients with *idiopathic short and long face*, the maxilla remained stable throughout the observation period.

The skeletal and soft tissue profiles were studied preoperatively on standardized radiographs and at 1 and 3 years postoperatively. The preoperative findings were compared with two reference groups, *i.e.* Sarnäs' adult male and female students and Dahl's adult cleft lip and palate males. Male patients with *cleft lip and palate* showed a similar profile to those reported by Dahl with but two exceptions. Maxillary retrusion was, for obvious reasons, more pronounced in the present material than in Dahl's, and the posterior height of the maxilla was greater than that of Dahl's, but agreed with that of Sarnäs' male students. The female cleft lip and palate patients showed a similar but smaller face.

Patients with *idiopathic anterior crossbite* had a short maxilla in a retruded position relative to the anterior cranial base. A long mandible and a large gonion angle contributed to increased total facial height. Consequently, the soft tissue contour revealed a flat facial profile.

Concerning patients with *idiopathic short or long face*, the alveolar process of the maxilla was either markedly underdeveloped or overdeveloped and the appropriate modification of Le Fort I osteotomy was used for correction.

One year after surgery, the facial profile of patients with *cleft lip and palate* and those with

idiopathic anterior crossbite showed significant improvement of maxillary position with elimination of anterior crossbite and marked improvement of the soft tissue profile. No further significant changes were noted at the 3 year follow-up.

From both functional and aesthetic points of view, the above study showed that maxillary mobilization by Le Fort I osteotomy can be a successful therapeutic modality for patients with a malposed and/or maldeveloped upper jaw.

APPENDIX

A detailed morphological study of the preoperative skeletal and soft tissue profile, tables 42—47, are printed separately and may be obtained from the author on request.

Tables showing changes in the postoperative skeletal and soft tissue profile are listed on the following pages.

TABLE 37.
Cleft lip and palate, males.

The facial profile before and 1 year after operation
compared with Sarnäs' and Dahl's reference groups

Changes in facial profile 1 and 3
years after operation

	Pre-op. n = 16	1 year after operation n = 10	Sarnäs' ref. group n = 145	Dahl's ref. group n = 153	1 year after operation n = 11		3 years after operation n = 8	
	m	m	m	m	d	P-level	d	P-level
<i>UPPER FACE</i>								
s-n-ss°	70.5	76.6	82.2	74.5	+4.6	***	±0.0	—
s-is vert	84.5	86.8			+1.5	*	-0.2	—
s-lc vert	83.3	83.9			+1.0	—	+0.1	—
<i>LOWER FACE</i>								
s-n-sm°	77.6	78.3	79.9	75.4	-0.1	—	-0.1	—
ML/-l°	78.0	76.5	94.6	82.7	+0.6	—	-0.3	—
Overjet	-3.8	2.7	4.2	-1.6	+5.9	***	+0.4	—
Overbite	2.2	1.8	2.9	2.6	±0.0	—	-0.2	—
Gonion angle	131.2	132.8	123.7	130.6	-1.2	**	-0.2	—
<i>TOTAL FACE</i>								
n-gn	132.8	134.6	126.4	129.9	-0.3	—	-0.3	—
NSL/ML°	35.7	36.5	29.8	38.1	-0.6	—	+0.3	—
<i>SOFT TISSUE</i>								
Thickness of upper red lip	13.2	11.1	14.7		-2.6	*	+0.1	—
Thickness of lower red lip	15.8	16.0	15.8		+0.7	—	-0.3	—
Depth of upper lip curv	10.0	10.8	9.5		+0.7	**	+0.2	—
Depth of lower lip curv	5.6	6.3	6.7		+0.9	*	+0.7	—
Lower lip height	51.6	53.6	47.8		-0.7	—	-0.3	—
NSL/NFL°	95.0	96.9	102.9		+0.5	—	-0.4	—
NFL/NCL°	152.1	151.9	140.1		-1.0	—	+0.1	—

TABLE 38.
Cleft lip and palate, females

The facial profile before and 1 year after operation compared with Sarnäs' reference group			Changes in facial profile 1 and 3 years after operation				
	Pre-op. n = 8	1 year after operation n = 7	Sarnäs' ref. group n = 172	1 year after operation n = 7		3 years after operation n = 6	
<i>UPPER FACE</i>	m	m	m	d	P-level	d	P-level
s - n - ss°	73.9	77.8	81.0	+4.5	**	+0.1	—
s - is vert	75.4	72.6		-3.4	—	+0.2	—
s - lc vert	71.8	70.0		-1.4	—	+0.1	—
<i>LOWER FACE</i>							
s - n - sm°	79.2	79.6	78.8	+0.5	—	-1.1	—
ML/-1°	78.8	77.3	94.3	-0.5	—	+0.7	—
Overjet	-4.6	2.0	4.1	+6.3	**	+0.5	—
Overbite	4.7	2.3	2.5	-3.3	—	+0.3	—
Gonion angle	132.7	128.8	125.7	-0.4	—	+0.5	—
<i>TOTAL FACE</i>							
n - gn	117.0	114.8	116.7	-2.5	—	+0.1	—
NSL/ML°	34.1	31.7	31.8	-1.2	—	+0.9	*
<i>SOFT TISSUE</i>							
Thickness of upper red lip	11.1	7.8	11.4	-3.0	—	+1.1	*
Thickness of lower red lip	12.5	12.4	13.1	-0.5	—	+0.7	—
Depth of upper lip curv	8.6	7.6	8.6	-0.3	—		
Depth of lower lip curv	4.2	3.8	5.6	-0.3	—	+0.5	—
Lower lip height	45.9	46.3	43.8	+0.4	—	+0.6	—
NSL/NFL°	93.4	95.2	99.3	+1.8	—	-0.4	—
NFL/NCL°	157.1	153.8	143.7	-2.8	—	-0.9	—

TABLE 39.

Idiopathic anterior crossbite, males

The facial profile before and 1 year after operation compared with Sarnäs' reference group.

Changes in facial profile 1 and 3 years after operation

	Pre-op. n = 38	1 year after operation n = 30	Sarnäs' ref. group n = 145	1 year after operation n = 30		3 years after operation n = 22	
<i>UPPER FACE</i>	m	m	m	d	P-level	d	P-level
s - n - ss°	75.7	82.5	82.2	+7.0	***	+0.2	—
s - is vert	87.3	89.3		+2.6	**	-0.3	—
s - lc vert	86.1	86.6		+1.0	—	+0.1	
<i>LOWER FACE</i>							
s - n - sm°	82.3	82.3	79.9	+0.3	—	+0.2	—
ML/ - 1°	76.3	78.2	94.6	+1.2	*	+0.7	—
Overjet	-5.3	2.8	4.2	+8.0	***	+0.1	—
Overbite	1.0	2.1	2.9	+1.0	—	-0.0	—
Gonion angle	136.2	135.1	123.7	-0.6	—	-0.2	—
<i>TOTAL FACE</i>							
n - gn	135.2	133.3	126.4	-0.9	—	+0.1	—
NSL/ML°	37.2	35.6	29.8	-1.0	—	-0.2	—
<i>SOFT TISSUE</i>							
Thickness of upper red lip	17.2	14.2	14.7	-3.9	***	-0.0	—
Thickness of lower red lip	14.7	15.3	15.8	±0.0	—	±0.0	—
Depth of upper lip curv	10.4	10.8	9.5	+0.3	—	-0.1	—
Depth of lower lip curv	4.0	5.2	6.7	+0.8	***	-0.1	—
Lower lip height	50.8	48.9	47.8	-0.8	—	-0.0	—
NSL/NFL°	100.2	100.5	102.9	+1.2	***	-0.0	—
NFL/NCL°	149.4	147.4	140.1	-2.5	***	+0.6	—

TABLE 40.

*Idiopathic anterior crossbite, females*The facial profile before and 1 year after operation
compared with Sarnäs' reference group.Changes in facial profile 1 and 3 years
after operation

	Pre-op. n = 25	1 year after operation n = 18	Sarnäs' ref. group n = 172	1 year after operation n = 18		3 years after operation n = 12	
<i>UPPER FACE</i>	m	m	m	d	P-level	d	P-level
s-n-ss°	76.7	82.8	81.0	+7.0	***	-0.5	*
s-is vert	80.5	81.2		+0.4	—	-0.1	—
s-lc vert	78.8	78.7		-0.3	—	+0.2	—
<i>LOWER FACE</i>							
s-n-sm°	82.5	82.6	78.8	+1.4	*	-0.4	—
ML/-1°	79.6	80.7	94.3	+0.3	—	+0.2	—
Overjet	-2.3	4.1	4.1	+6.5	***	+0.5	—
Overbite	1.3	2.4	2.5	+1.3	—	-0.2	—
Gonion angle	134.2	134.0	125.7	-0.7	—	-0.9	—
<i>TOTAL FACE</i>							
n-gn	122.5	119.5	116.7	-3.5	**	-0.1	—
NSL/ML°	35.9	33.9	31.8	-3.0	**	+0.7	—
<i>SOFT TISSUE</i>							
Thickness of upper red lip	14.0	12.2	11.4	-2.4	***	-0.1	—
Thickness of lower red lip	12.6	14.3	13.1	+1.5	*	-0.1	—
Depth of upper lip curv	8.7	9.5	8.6	+0.6	*	+0.1	—
Depth of lower lip curv	3.6	4.8	5.6	+1.0	***	±0.0	—
Lower lip height	46.0	44.9	43.8	-1.3	*	-0.5	—
NSL/NFL°	97.7	99.2	99.3	+1.4	***	-0.6	—
NFL/NCL°	151.7	148.9	143.7	-0.5	—	+0.4	—

TABLE 41.

Idiopathic short face, females

The facial profile before and 1 year after operation compared with Sarnäs' reference group.

Changes in facial profile 1 and 3 years after operation

	Pre-op. n = 5	1 year after operation n = 4	Sarnäs' ref. group n = 172	1 year after operation n = 4		3 years after operation n = 3	
<i>UPPER FACE</i>	m	m	m	d	P-level	d	P-level
s-n-ss°	79.3	78.3	81.0	-0.9	—	-0.2	—
s-is vert	70.5	76.6		+7.8	*	+0.2	—
s-lc vert	71.2	72.0		+2.3	*	±0.0	—
<i>LOWER FACE</i>							
s-n-sm°	81.1	79.3	78.8	-2.3	—	-0.5	—
ML/-1°	95.2	91.6	94.3	-2.6	—	+0.7	—
Overjet	4.8	5.3	4.1	-0.1	—	+0.3	—
Overbite	3.1	4.3	2.5	+1.5	—	-0.8	—
Gonion angle	114.2	113.3	125.7	-1.3	—	+0.2	—
<i>TOTAL FACE</i>							
n-gn	104.0	108.0	116.7	+5.3	*	+1.3	—
NSL/ML°	16.2	19.4	31.8	+3.6	*	+1.5	—
<i>SOFT TISSUE</i>							
Thickness of upper red lip	16.3	13.3	11.4	-1.4	—	+0.5	—
Thickness of lower red lip	16.8	15.8	13.1	-0.4	—	-0.7	—
Depth of upper lip curv	9.1	7.8	8.6	-1.1	*	+0.8	*
Depth of lower lip curv	6.6	6.0	5.6	-0.1	—	-0.3	—
Lower lip height	35.8	38.5	43.8	+2.8	*	-0.8	—
NSL/NFL°	98.4	98.0	99.3	-0.4	—	-0.8	—
NFL/NCL°	151.4	149.5	143.7	-2.3	*	+0.2	—

REFERENCES

- Adams, W. M.** 1942. Internal wiring fixation of facial fractures. *Surgery* 12, 523.
- Aitken, J. T., Causey, G., Joseph, J. & Young, J. Z.** 1971. A manual of human anatomy. Second II Ed. *Head and Neck*. Churchill Livingstone, Edinburgh and London.
- Aleman, O.** 1921. Ny operation för progeni. *Sv Tandläk tidskr* 14, 181.
- Antoni, A. A., Van de Mark, T. B., Weinberg, S. & Schofield, I.** 1965. Surgical treatment of long-standing malunited horizontal fracture of the maxilla. *J Canad Dent Ass* 31, 22.
- Axhausen, G.** 1934. Die Behandlung veralteter, disloziert geheilter Oberkieferbrüche. *Deutsch Z M K-heilk* 1, 334.
- Bell, W. H.** 1969. Revascularization and bone healing after anterior maxillary osteotomy. *J Oral Surg* 27, 249.
- Bell, W. H. & Levy, B. M.** 1971. Revascularization and bone healing after posterior maxillary osteotomy. *J Oral Surg* 29, 313.
- Bell, H. B.** 1973. Biologic basis for maxillary osteotomies. *Am J Phys Anthropol* 38, 279.
- Björk, A.** 1955. Facial growth in man, studied with the aid of metallic implants. *Acta Odont Scand* 13, 9.
- Björk, A.** 1960. The relationship of the jaws to the cranium. *Introduction to Orthodontics* (A. Lundström ed.), 104. Mc Graw-Hill. Co., London.
- Björk, A. & Solow, B.** 1962. Measurements on radiographs. *J Dent Res* 41, 672.
- Björk, A.** 1963. Variations in the growth pattern of the human mandible: A longitudinal radiographic study by the implant method. *J Dent Res* 42, 400.
- Björk, N., Eliasson, S. & Wictorin, L.** 1971. Changes of facial profile after surgical treatment of mandibular protrusion. *Scand J Plast Reconstr Surg* 5, 41.
- Cernéa, Grignon, Crépy & Benoist.** 1955. Les osteotomies totales des maxillaires supérieurs. *Rev Stomat* 56, 700.
- Converse, J. M. & Shapiro, H. H.** 1952. Treatment of developmental malformations of the jaws. *Plast Reconstr Surg* 10, 473.
- Cupar, I.** 1954. Die chirurgische Behandlung der Form — und Stellungsveränderung des Oberkiefers. *Österr Z Stomat* 51, 565.
- Dahl, E.** 1970. Craniofacial morphology in congenital clefts of the lip and palate. *Acta Odont Scand* 28, Suppl. 57.
- Dingman, R. O. & Harding, R. L.** 1951. Treatment of malunion fractures of facial bones. *Plast Reconstr Surg* 7, 505.
- Fromm, B. & Lundberg, M.** 1970. The soft tissue facial profile before and after surgical correction of mandibular protrusion. *Acta Odont Scand* 28, 157.
- Gillies, H. G. & Rowe, N. L.** 1954. L' osteotomie du maxillaire supérieur envisagée essentiellement dans les cas de bec-de-lièvre total. *Rev Stomat* 55, 545.
- Hald, A.** 1952. Statistical theory with engineer application. Wiley & Sons, New York.
- de Haller C.** 1969. Ergebnisse des operativen Vorbringens des Oberkiefers. Inaug. Diss, Zürich.
- Hallert, B.** 1967. Elementär felteori för mätningar. Nordstedt & Söners förlag.
- Hogeman, K. E.** 1951. Surgical — orthopaedic correction of mandibular protrusion. *Acta Chir Scand Suppl* 159.
- Hogeman, K. E.** 1956. Die Behandlung von Oberkieferfrakturen ohne extraorale Stützverbände. *Fortschr Kiefer — u Gesichts-Chir* 11, 49. G. Thieme, Stuttgart.
- Hogeman, K. E. & Willmar, K.** 1967. Die Vorverlagerung des Oberkiefers zur Korrektur von Gebissanomalien. *Fortschr Kiefer — u Gesichts-Chir* 12, 275. G. Thieme, Stuttgart.
- Hviid, J.** 1972. Icke-handikappades reaktioner over for handicappade. Disputats, Köbenhavn.
- Immenkamp, A.** 1938. Die chirurgisch — orthopädische Versorgung älterer Spaltträger. *Deutsch Z M K-heilk.* 5, 824.
- Kiehn, C. L., Desprez, J. D. & Brown, F.** 1968. Maxillary osteotomy for late correction of occlusion and appearance in cleft lip and palate patients. *Plast Reconstr Surg* 42, 203.
- Kostecka, F.** 1937. Horizontale Osteotomi beider Zweige des Unterkiefers zwecks Anbringung einer Prothese (bei Progenie) *Ceskosl Stomat* 37, 735.
- Kufner, J.** 1971. Four — year experience with major maxillary osteotomy for retrusion. *J Oral Surg* 29, 549.
- Köle, H.** 1963. Ergebnisse, Erfahrungen und Probleme zur operativen Behandlung der Progenie. *Deutsch Z M K — heilk* 40, 177.

- Lane, A. 1905. Cleft Palate and Harelips, London.
- Leibold, D.G., Tilson, H.B. & Rask, K.R. 1971. A subjective evaluation of the re-establishment of the neurovascular supply of teeth involved in anterior maxillary osteotomy procedures. *Oral Surg* 32, 531.
- Lévigat, J. 1958. Traitement d'un enfoncement consolidé du tiers moyen de la face par ostéotomies et greffes d'os. *Rev Stomat* 59, 551.
- Lindegård, B. 1953. Variations in human body-build. *Acta Psych Neurol Scand.* Suppl 86.
- Mohr, A. M. 1967. Maxillary osteotomy for the correction of malpositioned fractures: report of case. *J Oral Surg* 25, 460.
- Moore, F. F. & Ward, F. G. 1949. Complications and sequelae of untreated fractures of the facial bones and their treatment. *Brit J Plast Surg* 1, 262.
- Mårtensson, G. 1950. Dental injuries following radical surgery on the maxillary sinus. *Acta Otolaryng* Suppl 84.
- Nomina Anatomica 1968. Third Ed. *Excerpta Medica Foundation.* Mouton, Hague.
- Obwegeser, H. L. 1965. Eingriffe am Oberkiefer zur Korrektur des progenen Zustandsbildes. *Schweiz Mschr Zahnheilk* 75, 365.
- Obwegeser, H. L. 1967. Zur Behandlung der veralteten Oberkieferfrakturen. *Fortschr Kiefer-u Gesichtschir* 12, 126. Georg Thieme, Stuttgart.
- Obwegeser, H. L. 1969. Surgical correction of maxillary deformities. In: Grabb, W. C., Rosenstein S. W., Brock K. R. *Cleft Lip and Palate.* Little, Brown, Boston.
- Paul, J. K. 1969. Correction of maxillary retrognathia: report of case. *J Oral Surg.* 27, 57.
- Peppersack, W. J. 1973. Tooth vitality after alveolar segmental osteotomy. *J Max-Fac Surg* 1, 85.
- Perco, M. 1972. Maxillary sinus and surgical movement of maxilla. *Int J Oral Surg* 1, 177.
- Pichler, H. 1929. Die orthopädische Kieferresektionen. *Fortschr Zahnheilk* 5, 1037.
- Poswillo, D. 1972. Early pulp changes following reduction of open bite by segmental surgery. *Int J Oral Surg* 1, 87.
- Rauber — Kopsch. *Lehrbuch und Atlas der Anatomie des Menschen.* Bd 4, 1922. Bd 5, 1923. Georg Thieme, Leipzig.
- Rontal, E. & Hohmann, A. 1972. Lateral alveolo-maxillary osteotomies. *Arch Otolaryng* 95, 18.
- Sarnäs, K. V. 1959. Inter- and intra-family variations in the facial profile. *Odont Rev* 10, Suppl 4.
- Sarnäs, K. V. 1973. The adult facial profile. A radiographic study of 317 male and female students aged 19–23 years. (Manuscript, to be published).
- Schuchardt, K. 1942. Ein Beitrag zur chirurgischen Kieferorthopädie unter Berücksichtigung ihrer Bedeutung für die Behandlung angeborener und erworbener Kieferdeformitäten bei Soldaten. *Deutsch Z M K-heilk* 9, 73.
- Sicher, H. 1949. *Oral Anatomy.* C.V. Mosby, St. Louis.
- Solow, B. 1966. The pattern of craniofacial associations. *Acta Odont Scand*, 24 Suppl 46.
- Steinkamm, W. 1938. Die Pseudo-Progenie und ihre Behandlung. Inaug Diss, Berlin.
- Thoma, K. H. 1963. *Oral Surgery*, 1130. Fourth ed. Mosby Co. Saint Louis.
- Trauner, R. & Obwegeser, H. 1957. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty. *Oral Surg* 10, 677.
- Trauner, R. 1973. *Kiefer- und Gesichtschirurgie*, 270. Urban und Schwarzenberg, München – Berlin – Wien.
- Ullik, R. 1970. Erweiterte Osteotomie des Oberkiefers. *Österr Z Stomat* Heft 4, 122.
- Walker, R. V. & Collins, T. A. 1971. Surgery or Orthodontics — A philosophy of approach. *Dent Clin N Amer* 15, 771.
- Ware, W. H. & Ashamalla, M. 1971. Pulpal response following anterior maxillary osteotomy. *Am J Orth* 60, 156.
- Wassmund, M. 1935. *Lehrbuch der praktischen Chirurgie des Mundes und der Kiefer.* Bd I, 260, 282. Hermann Meusser, Leipzig.
- Widmaier, W. 1960. Die chirurgische Behandlung der postoperativen Kieferdeformierungen nach Lippen – Kiefer – Gaumenspalten – Operationen. *Deutsch Z M K-heilk* 33, 23.
- Willmar, K., Hogeman, K. E. & Sarnäs, K. V. 1973. Surgical and dental-orthopaedic correction of maxillary deformity in adults with operated cleft lip and palate. Paper presented at the 2nd International Congress of Cleft Palate, Copenhagen 1973. (To be published).

